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JOURNAL OF THE AERONAUTICAL SCIENCES

Volume 4 MARCH, 1937 Number 5

High Altitude Airplane Compartments

JAMES S. McDONNELL, JR., *The Glenn L. Martin Company*

Presented at the Long Range Seaplane and Airship Problems Session, Fifth Annual Meeting, I. Ae. S. January 27, 1937

ABSTRACT

A sudden decrease of pressure from 14.5 to 5.5 lbs. per sq. in. did not harm personnel, and alleviated sinus trouble. Contingent oxygen deficiency produced no annoying oxygen-want at 25,000 feet until 5.0 to 7.8 minutes because the suddenness of the change left body fully oxygenated. In case of a punctured pressure compartment the flight engineer need simply add oxygen to the air conditioning system.

Structural Tests: Two duralumin cylinders each 5 ft. in diameter and 12 ft. long were pumped up 7,300 times to pressure differential of 11.5 lb. per sq. in. A conventional "fixed skin" monocoque structure was compared to "floating skin" structure. Three types of rivets and five types of sealing materials were tested.

Sealed pressure cabins can be constructed for a pressure differential of 5.0 lbs. per sq. in. at little weight increase except for windows if fuselage has circular section. For a protruding cockpit as compared to being "flush" with the streamline surface of revolution the weight penalty was over 400 lbs. on a 55,000 lb. airplane.

Air Conditioning: The source of pressure is preferably a 40,000 r.p.m. centrifugal blower, driven electrically by an 800 cycle alternator. Alternatively, air bled from an engine turbo-supercharger is flavored by the alcohol odor from the propeller de-icer. The air heating load is so reduced by the centrifugal blower and recirculation of over 90 per cent of the air that electrical heating is a most attractive solution. Activated charcoal is a good deodorizer; ozone is positively injurious.

Conclusion: Sealed pressure-oxygen compartments can now be successfully constructed for operation to 30,000 feet.

INTRODUCTION

THE urge towards smoother flying, more frequent completion of scheduled flights and increased speed by flying at higher altitudes above the weather makes the design of pressure and oxygen compartments of special interest at this time.

EXPERIMENTS ON PERSONNEL IN PRESSURE COMPARTMENT

One of the first problems is whether the sudden accidental loss of pressure will injure personnel inside a pressure compartment. Such puncturing of the compartment could come from a bullet or a broken propeller blade or from a duck smashing the cockpit windshield as actually happened on a United Airliner one winter night in 1935.

To help answer this question R. E. Whitehead, Chief of the Medical Section, Bureau of Air Commerce, kindly arranged for the use of the Bureau of Standards decompression chamber through the courtesy of W. G. Brombacher. Puncturing the pressure compartment was simulated by evacuating the decompression chamber as rapidly as possible. The results are summarized in Table 1. In the chamber throughout the tests were Whitehead and two "normal" subjects: the writer as "Subject A," and Subject B who was suffering from sinus trouble prior to the tests.

TABLE 1

TEST NO. 2. TO DETERMINE EFFECT ON CONTAINED PERSONNEL OF PUNCTURING A PRESSURE COMPARTMENT.

Pressure Altitude (feet)	Elapsed Time (minutes)	NOTES
480	0	3 Air pumps start evacuating chamber.
10,000	1.4	This simulated loss of pressure in 1.4 minutes in an airplane pressure compartment carrying 14.5 lbs./sq.in. at 10,000 ft. (10.1 lbs./sq.in.). No ill effects whatsoever on Subjects A or B.
10,000	11.5	10.1 minutes spent at 10,000 ft. Evacuation then renewed.
25,000	14.3	This simulated loss of pressure in 2.8 minutes in a pressure compartment carrying 10,000 ft. pressure (10.1 lbs./sq.in.) at 25,000 ft. (5.5 lbs./sq.in.). No ill effects or discomfort whatsoever from this sudden decrease in pressure. Without benefit of instruments the subjects might have detected the change only by the following harmless effects: occasional hearty eructation, passing of gas at the anus, and SUBJECT B EXPERIENCED DISTINCT RELIEF FROM THE SINUS PAINS WHICH HAD ANNOYED HIM FOR SEVERAL DAYS PREVIOUS and this improvement lasted for a day thereafter. No deficiency of oxygen could be noted immediately because the jump to 25,000 ft. had been so rapid that lungs and blood were still fully oxygenated. The 400 c.c. of oxygen normally carried in reserve in the body, plus the reduced available supply, were sufficient for several minutes.
25,000	19.3	Only after 5.0 minutes did Subject A experience the usual signs of anoxemia and resort to the oxygen tube.
25,000	22.1	Only after 7.8 minutes did Subject B experience signs of anoxemia and resort to the oxygen tube.
25,000	44.3	After 30 minutes at 25,000 ft., taking oxygen through tubes, the descent was started.
400	50.5	Pressure increase from 5.5 to 14.5 lbs./sq.in. in 6.2 minutes elapsed time, or 1.38 minutes exclusive of stops. Subject A had no ill effects. Subject B had intense pain in sinus; headache continued for 10 minutes.

EXPERIMENTS ON PERSONNEL IN OXYGEN COMPARTMENT

After simulating puncturing a pressure compartment at 25,000 feet, in Test No. 1, oxygen was taken through a rebreather, and in Test No. 2 oxygen was taken through a tube in the mouth which caused saliva to flow freely from Subject A's mouth. Both of these oxygen supply methods would be undesirable for passenger use, so in Test No. 3 oxygen was simply discharged into the chamber so as to increase the partial pressure, thus making the chamber into a so-called "oxygen compartment." The results are shown in Table 2.

CONCLUSIONS RELATIVE TO PERSONNEL

The conclusions drawn relative to the "normal" personnel tested were that if the pressure is suddenly changed in a pressure compartment in the range of 14.5 to 5.5 lbs. per sq. in.:

(1) Sudden increase in pressure causes pain and can even incapacitate contained personnel.

(2) Sudden decrease in pressure not only causes no injury or discomfort to contained personnel, but even alleviates sinus trouble. This is indeed good for higher altitude flying.

(3) The contingent sudden decrease in the partial pressure of oxygen is alleviated by the 400 c.c. of oxygen normally carried in reserve in the body, so that anoxemia is delayed for several minutes.

(4) On commercial passenger planes the best way to supply the additional oxygen required is probably simply to enrich with oxygen the air circulated throughout the whole air conditioning system.

OPERATING TECHNIQUE

The operating technique in case of window breakage at 25,000 feet in a pressure cabin might be as follows. A red light could warn the flight engineer in case of decrease of pressure below a pre-determined

TABLE 2

TEST NO. 3. TO DETERMINE BEST WAY OF SUPPLYING OXYGEN TO CONTAINED PERSONNEL AFTER PUNCTURING A PRESSURE COMPARTMENT.

Pressure Altitude (feet)	Elapsed Time (minutes)	NOTES
480	0	
25,000	5.7	This simulated sudden decrease in pressure from 14.5 to 5.5 lbs./sq.in. No ill effects Oxygen was immediately released into the chamber through the 3 small hoses, which were this time simply laid on the table instead of being placed in the mouth as in Test No. 2.
25,000	22.0	After 16.3 minutes at 25,000 ft. there were no ill effects except a slight dizziness, and it was agreed that this was a much pleasanter way to take oxygen, than through a tube in the mouth in Test No. 2 and through a re-breather in Test No. 1.
6,000	22.58	Increase of pressure from 5.5 to 11.8 lbs./sq.in. in 35 seconds. Subject A had severe pain in left ear. Subject B felt fine.
4,500	22.7	Increase in pressure from 11.8 to 12.5 lbs./sq.in. in 6.8 seconds. Subject A practically incapacitated. Subject B felt fine.
400	....	Chamber opened.

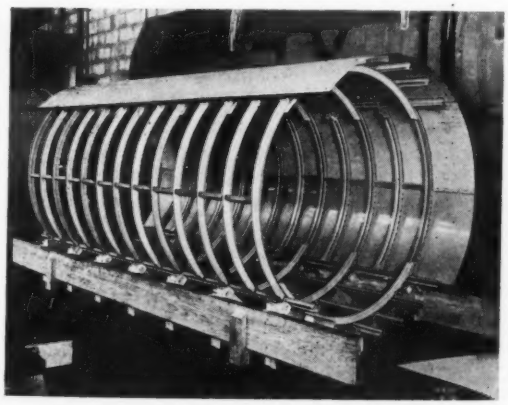

FIG. 1. "Fixed skin" test cylinder.

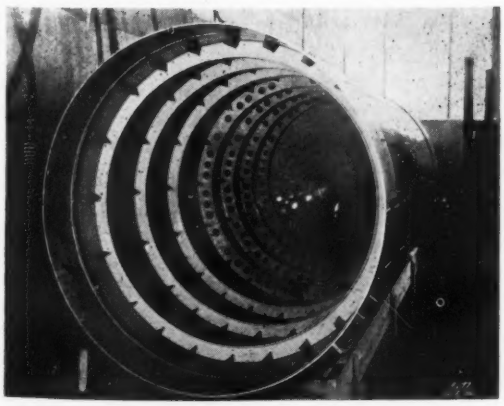

FIG. 2. "Floating skin" test cylinder.

point. The flight engineer's duty would be to immediately turn a lever to supply the required oxygen enrichment to the air conditioning system. It should be the duty of the steward to place a seal over the broken window. While the pressure was gradually restored the airplane could proceed on schedule at 25,000 feet.

Thus as a safe and sure first step towards flying above the weather, sealed pressure-oxygen compartments using a medium pressure differential of about 5 lbs. per sq. in., with oxygen in reserve, appear very attractive.

STRUCTURAL TESTS ON PRESSURE CYLINDERS

When a pressure compartment is pumped up the hoop stress elongates the skin. One of the first questions that arises is whether the structure should be so designed that the skin and longitudinal stringers can "float" relative to the transverse frames so as to try to avoid local concentrations of stress, or whether sufficient durability can be obtained with conventional monocoque structure. The only way this question can really be settled is by testing specific "floating skin" and "fixed skin" structures.

Fig. 1 shows a "fixed skin" test cylinder 5 ft. in diameter and 12 ft. long. Skin, stringers and transverse frames are riveted solidly together.

Fig. 2 shows a "floating skin" test cylinder of the same size. The longitudinal stringers are riveted only to the skin; they are free to float relative to the transverse frames. The skin in turn can enjoy considerable movement relative to the transverse frames by virtue

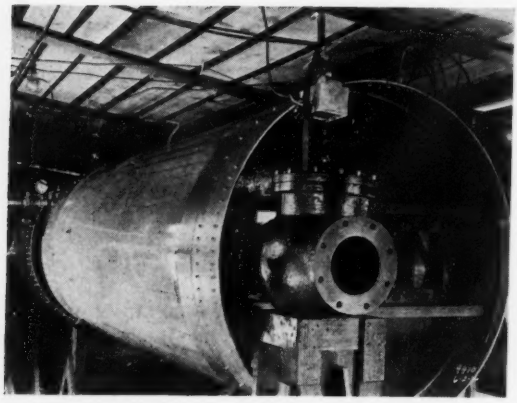

FIG. 3. Test cylinder hooked up.

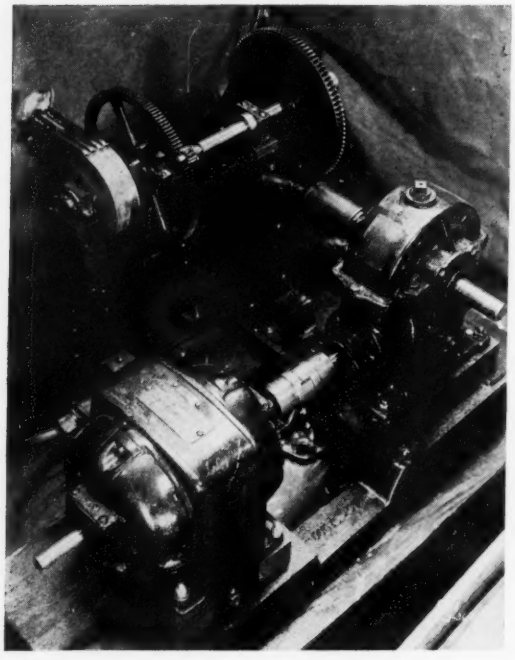

FIG. 4. Automatic timing mechanism.

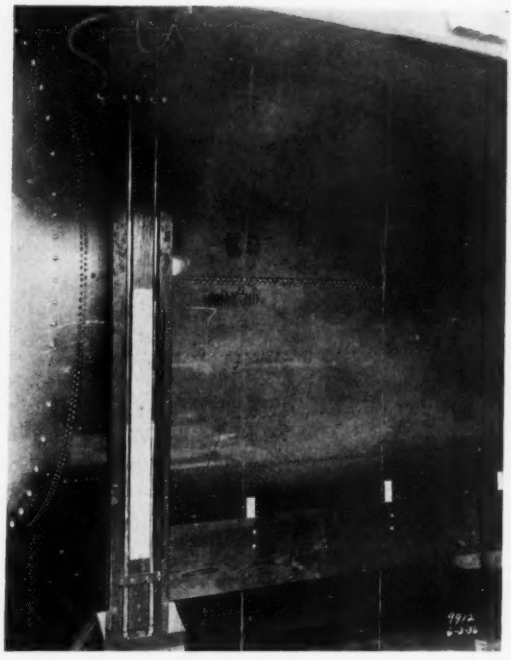

FIG. 5. Strain gauges, riveted seams, etc.

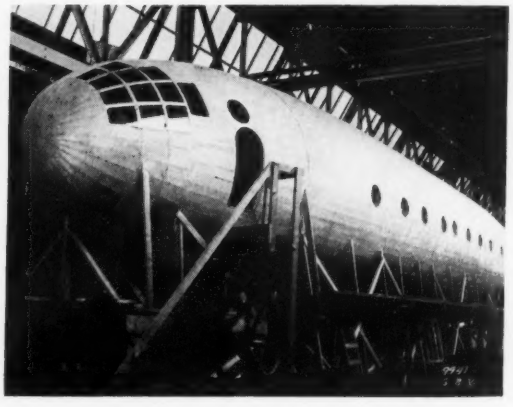

FIG. 6. Pressure cockpit viewed from the outside.

of being riveted to them near the outer edge of flanges 1¾ in. wide. Both test cylinders had 0.032 in. skin, which is about what would have been required aside from pressure compartment considerations.

Fig. 3 shows the two cyinders assembled with an observation window at each end. They were equipped with an intake valve and an 8 in. exhaust valve, both automatically operated electrically.

Fig. 4 shows the electrical mechanism which controlled pumping up and exhausting the pressure cylinders automatically day and night to a total of 7,300 of the following cycles:

	Minutes
Pump up to 11.5 lbs. per sq. in. pressure differential	2.0
Hold above pressure	0.17
Release pressure	
Idle	5.33
Total cycle	7.5

Fig. 5 shows a close-up of the pressure gauge and the strain gauges. The latter consisted simply of steel piano wire wrapped around the cylinders, with pointers attached to the wires opposite appropriate gauges.

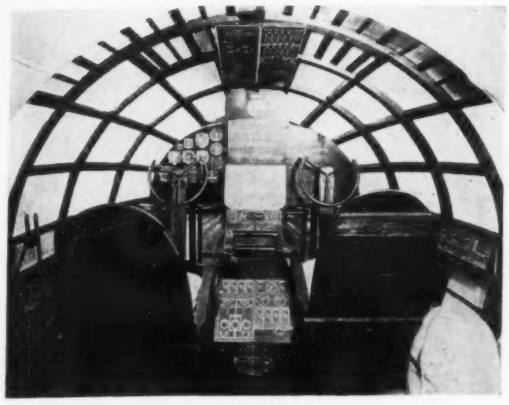

FIG. 7. Visibility from pressure cockpit.

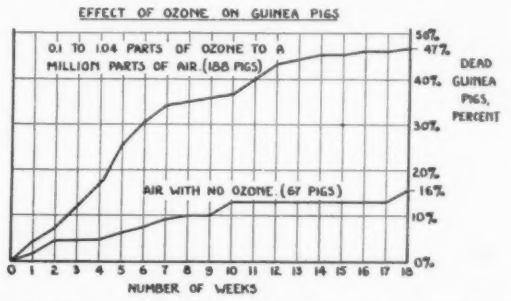
EFFECT OF OZONE ON GUINEA PIGS
0.1 TO 1.04 PARTS OF OZONE TO A MILLION PARTS OF AIR (188 PIGS)
AIR WITH NO OZONE (67 PIGS)
DEAD GUINEA PIGS, PERCENT
50%
47%
40%
30%
20%
16%
10%
0%
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
NUMBER OF WEEKS

FIG. 8. Effect of higher concentration. 1 part of ozone to 370 parts of air inhaled by 7 guinea pigs for 5 minutes resulted in death of all after 8 to 9½ minutes. Based on researches of Professor H. B. McDonnell, University of Maryland.

Fig. 5 also shows the types of rivets tested, viz., mushroom, brazier, and flush heads, and 17ST and A17S aluminum alloys. The types of sealing materials tested were Duprene strip, Copalit cement and liquid, Fostoria Tite Seal and Thiokol No. 207 liquid.

After putting the test cylinders through 7,300 pressure cycles, which exceeds the normal life of a high altitude airplane, the author was confident that sealed pressure-oxygen compartments could be successfully built for medium altitude flying up to 30,000 feet, at a pressure differential of about 5.0 lbs. per sq. in. On the above basis for a particular airplane illustrated below no increase in skin thickness was required beyond the 0.032 in. which would have been necessary even without the internal pressure. This is another guide to medium pressure and an upper limit of about 30,000 feet as an attractive first step.

COCKPIT

What to do with the cockpit in a pressure compartment is an open question. A detailed analysis indicated that if the circular cross section of the body were broken by superimposing a conventional cockpit upon it, the decrease in cruising speed of less than 1 m.p.h. would not be serious, but the increase of over 400 lbs. in structural weight, as compared to the next type to be described, would be very objectionable.

Another type of solution would be to make the cockpit windshield part of the streamline surface of revolution, as illustrated in Fig. 6. From the inside this gives the forward visibility illustrated by Fig. 7.

SOURCE OF PRESSURE

The air conditioning system must start from a source of pressure. The readiest source is to be found in the engine turbo-supercharger, which can conveniently be bled of enough air to easily take care of the cabin pressure. But this means that the cabin air comes in through the engine air intake which unfortunately can not conveniently be mounted any place except in the propeller slipstream. For high altitude work propellers will have to be equipped with de-icers throughout the year, and unfortunately the essential part of these de-icers is the mixture of glycerine and alcohol or its equivalent, which is thrown centrifugally along the leading edge. Just a trace of alcohol in the cabin air will be sufficient to condemn the engine turbo-supercharger as a pressure source.

The problem of a pressure source is not difficult however, because all requirements can be readily met with a compact little centrifugal blower turning at 40,000 r.p.m. (with a supersonic tone) by an 800 cycle alternator. The weight is relatively so low that such an installation can be doubled for reliability on a 40 passenger airplane at the following penalty:

2 Centrifugal blowers at 10 lbs.	=	20 lbs.
2 4.5 kw. 800 cycle alternators at 25 lbs.	=	50 lbs.
Total		70 lbs.

The centrifugal blower and the electrical alternator are both very simple and reliable.

HEATING

In passing through the centrifugal blower the air has its temperature raised about 64° F. At the same time, in a sealed cabin with a completely closed circuit air conditioning system which circulates 30 cu. ft. of air per passenger per minute, in order to keep the carbon dioxide content of the air correct it is desirable to exhaust on each round less than 10 per cent of the above 30 cu. ft. This heat conserving factor, plus the heat from the centrifugal blower, reduces the additional heat required to a peak load of about ¼ kw. per passenger seat, and to an average of probably less than 0.1 kw. per passenger seat. Thus heating can be economically taken care of by a clean and flexible electrical system having long life and low maintenance cost.

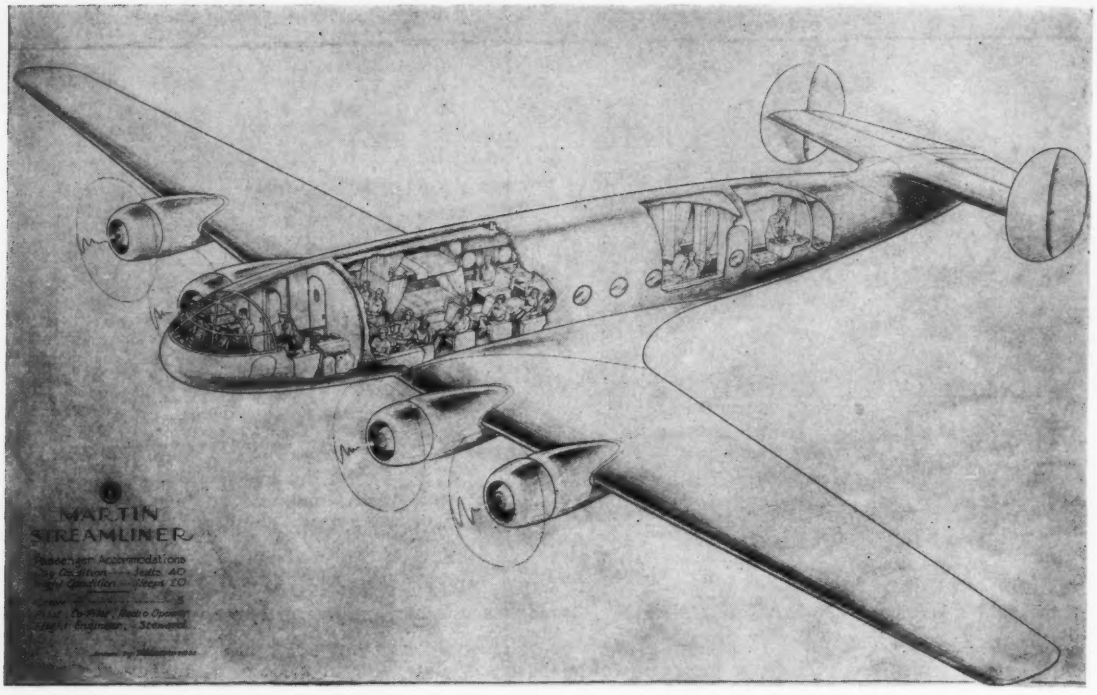

FIG. 9.

DEODORIZING

The use of a closed circuit air-conditioning system discharging less than 10 per cent of the air on each round, makes mandatory the use of a good deodorizer. There is a widespread opinion in this country that ozone is not only an effective deodorizer, but also is very healthful. The country's best researches on ozone were therefore sought out, with the authoritative results shown in Fig. 8 from a monograph published by H. B. McDonnell of the University of Maryland in 1929.

Ozone is highly injurious to both guinea pigs and men. Quoting from a monograph published by E. O. Jordan and A. J. Carlson, published in 1913 by the American Medical Association:

"In concentrations that appreciably affect man and animals, ozone appears to have uniformly an injurious action. This injurious action is primarily on the respiratory passages—irritation of the sensory nerve endings and irritation, corrosion and depression of the epithelial cells."

Likewise contrary to popular opinion, ozone is not an actual "deodorizer" in concentrations that can be obtained in practical ventilation. The only reason these negative results relative to ozone are published here is because of its dangerous nature. Some deodorizer is, however, essential and it would appear that the price, in pressure head necessary to force the recirculated air through some such deodorizer as activated charcoal, will be well spent.

CONCLUSION

Nature has facilitated man's path to higher altitude flying in sealed pressure-oxygen compartments by providing four lucky aids:

(1) Sudden decrease in pressure within the limits involved is in all probability not injurious to personnel. Punctured pressure compartments will therefore not be dangerous.

(2) After a sudden decrease in pressure anoxemia does not become dangerous for several minutes, thus allowing ample time to rectify the situation by more oxygen or descending to a lower altitude.

(3) The fuselage cross section shape which is perfect for withstanding internal pressure, *viz.*, the circle, is also the shape which gives the lowest aerodynamic drag in the form of a streamline surface of revolution.

(4) Heating sealed pressure compartments is rendered easy because of two facts: the centrifugal blower required for pressure also supplies heat, and the carbon dioxide content required by human beings makes it necessary to discharge less than 10 per cent of the circulated air per round.

Whether conclusions (1) and (2) are equally valid for all human beings can only be determined by much more elaborate research. The author feels, however, that from the aircraft construction viewpoint, it is safe to conclude that sealed pressure-oxygen compartments can now be successfully constructed for operation to 30,000 feet on the wings of such a typical airplane of the future as illustrated by Fig. 9.

The author wishes to acknowledge the assistance of Wm. P. Kennedy in the preparation of this paper.

Weather as a Factor in the Proposed Lindbergh Memorial Race

JAMES H. KIMBALL, *U. S. Weather Bureau*

Presented at the Meteorology Session, Fifth Annual Meeting, I. Ae. S.
January 28, 1937

THE Lindbergh Memorial Race, since first proposed last summer at the F.A.I. meeting, has had critical consideration both here and abroad, in an endeavor to safeguard the project against normal hazards. Several features remain to be adjusted, but much progress has been made in formulating suitable regulations. The start is to be under the control of the N.A.A., which organization will pass on the credentials of the applicants and give the signal to start.

Among the most important of the changes in the original plan is that which has to do with the time of starting. Originally, the date was set for May 20th, next, the 10th anniversary of the Lindbergh Flight. This was found to be too early in the season from consideration of the following experience.

The Hinchcliffe flight took off for a westward crossing on March 12, 1928 and was lost at sea. The Bremen left Ireland April 4, 1928, and was the first successful non-stop west bound crossing, but only reached Newfoundland. Nungessor and Coli left Paris the preceding year on May 8th and were lost at sea. Riechers, who took off from Newfoundland, May 13, 1932, was picked up near the Irish coast. Pond and Sabelli left Floyd Bennett Field, May 15, 1934, bound for Rome, and reached Ireland. Miss Earhart flew safely through 5 hours of bad weather in mid-ocean on May 20th, 1932, but was forced down in Ireland, and Rossi and Codos began the record long distance flight one week later.

This enumeration showed a percentage of failure that prompted the postponement of the start until midsummer.

The race is open only to multi-motored, heavier than air craft. The pilot must hold a pilot's license, also a sporting license for the current year. Each competitor must show adequate proof that one member of the crew has ability as an aerial navigator and radio operator. The aircraft must be equipped with a radio telegraphic apparatus for sending and receiving. This set-up precludes the possibility of a solo flight.

Each contestant must accompany his application with a fee of 5,000 francs—which is to be returned, proportionately with the prizes of 1,500,000 francs, 1,000,000 francs, and 500,000 francs to the first, second and third of the contestants to arrive at Paris.

The regulations in their present form permit the start to be made any suitable day next August. It is (on paper) to be a race against time, the speed to be considered for all contestants reaching Paris, within 60 hours.

The starting committee *must* postpone the start if the weather at the field (Floyd Bennett) is judged to be unsuitable. Presumably, this contemplates a local storm, fog, or a cross-wind, on the proposed runway.

This decision is not a simple one, since conditions good enough for one pilot may be impossible for another. Also, the committee must pass on the weather over the ocean and come to a conclusion that it shows no unreasonable hazard then, or in prospect, within the next following 36 hours. Herein lies another embarrassing situation, for the committee must appraise the obstacles, as to storminess, cross or head winds, ice bearing clouds keeping in mind the weakest of the contestants.

Furthermore, the decision to start will be quite as perplexing for the pilot who is out to win the race, as it will be for the committee, since the pilot will know that the man who flies the worst weather will have the greatest assistance from the wind. The pilot will also have to decide on how much blind flying he can do. The flight may be with or without stops.

The committee is not authorized to say that the weather *is* suitable. The pilot is privileged to take-off, or not, after the starting signal is given.

Such an arrangement means that the most daring pilot will start as soon as the signal is given, and that probably the others will trail along knowing that, at best, there are only a few days in the summer when the flight is possible.

To service such a proceeding the starting committee must stand in readiness from July 31st until the last remaining contestant has left or declared his intention to withdraw; and the committee must be prepared to pass on the weather hazard twice each 24 hours. In order to insure a daytime landing in Paris the contestants must start in the forenoon, and the decision to start must be made tentatively 24 hours earlier from weather reports that are then from 4 to more than 6 hours old. Twelve hours later the starting committee must make the final decision.

Unless some special provision is made to expand the reporting service the starting committee must make its weather analysis from reports received from, let us say, 10 vessels—only 1 or 2 of which may be within 100 miles of the great circle course. Each observation will include the surface wind direction and velocity, barometric pressure, temperature, state of the sky and visibility. There will be nothing on wind, temperature or humidity aloft, or the height or thickness of the clouds.

Notwithstanding, an ample weather survey *may* be forthcoming at the time or times it is needed. Assume then for the sake of argument that a good scatter of reports is placed at the disposal of the starting committee. Their interpretation is then demanded. Many surveys are simple but even that fact must be determined; and there will be other occasions where some new development comes to light that must be appraised as to its influence a day or two later on airplanes flying in various levels from 2,000 to more than 15,000 feet. Such problems have phases that are entirely new to students whose background is a study of supposedly similar conditions over a land mass.

The author asks that you visualize with him 10 airplanes on the starting line. Everyone of these ships will be as nearly perfect as the industry can make it. Tests will have shown that the craft can make a non-stop flight of at least 2,000 miles, and that it will be piloted by men of known skill and resourcefulness. Then consider the experience of *the other "perfect"* airplanes that have attempted the Atlantic crossing. There is no way of knowing how many of those met disaster because of pilot insufficiency, but it is known from over-land experience that nearly 50 per cent of the disasters are attributable to personnel. It is also known that an embarrassingly large percentage of the craft that have made safe Atlantic crossings have developed weaknesses, in the airplane, the motor, the instruments, the fuel, the lubricant or the feed lines.

The utmost that can be done to safeguard this flight is to place 10 weather reporting vessels equidistant from one another over a zone 500 miles wide stretching from shore to shore. Place on each a meteorological unit equipped to fly pilot balloons by means of which wind-directions and wind-velocity may be determined at various altitudes; and radio-meteorographs, supplemented by seaplanes, that can bring to the meteorologist the temperature and the humidity in the overlying air blanket. Then connect this network with a wireless reporting service by which the meteorologist may collect the material, and there will have been provided the *least* that the contestants should have for their protection.

It will be the least for the reason that no such network will work perfectly. The balloons, many of them, will disappear from view before they reach an elevation of 2,000 feet and thus return nothing of value to contestants flying at 10,000 feet. And, of the sounding airplanes or radio-meteorographs, some, for one reason or another, will fail.

But given the possibility of satisfactory functioning of this system on the day of the take-off; is it reasonable to expect it to operate, say twice-daily from July 25th until the last of the contestants takes off? The experience that obtained with a trained organization spread from one side of the continent to the other gives an answer well known to all.

It is the belief in local aviation circles that many failures to make a safe Atlantic crossing were primarily due to fatigue and consequent faulty piloting.

If this view is correct, emphasis in safeguarding this flight should be built about the selection of the pilots. It may be taken for granted that these men will rank with the best in their profession in experience, resourcefulness and general capacity. No doubt they will have been through the most grilling tests known to land flying. But over-water flying is, in one important aspect, quite different. There is no fair basis of comparisons between a struggle that has in it the likelihood of a landing with only minor injuries, and one in which a failure is complete and final.

What is required for an Atlantic crossing is emotional stability of the quality that can withstand, hour after hour at night, a struggle in clouds in which a momentary failure of judgment spells disaster. Perhaps it is impossible to provide an emotional test that will eliminate men of inherent instability, but at least the starting committee should be empowered to refuse admission to men who are obviously unfit.

This then brings up another embarrassing situation. Where can men be found to take control whose standing is such as to place them above charges of favoritism?

What useful purpose can be claimed for this flight? Before the start, it has been stripped of the qualities that justify its being named a Lindbergh Memorial Race. It is not to take off on May 20th, the date of the first non-stop flight. It cannot be a solo crossing. It will not represent the effort of a small group and one pilot preparing for something that has never been done before. It is inconceivable that the winner of this race, despite the advance that has been made in every line of aviation and piloting, backed by unlimited resources, can do more than shorten the time of the perfect flight it is intended to memorialize. Suppose the flight is made in 20 hours. Of course that would be a creditable performance but what of the airplane that finishes in 33 hours, the time required for the Lindbergh crossing; of those that crack up in Europe, those that come down at sea, and those that do not get-off for a start.

With the publicity that is built up for this event there will be world-wide acclaim for the winner for one day —perhaps two—but what will be read on the front pages on the next succeeding days? Something that will be sure to place both the starting committee and industry in a very embarrassing position.

Please do not misunderstand the author. It is believed that the Atlantic will be flown as a matter of routine in the not-far-distant future. But the project will be best advanced by trial flights following the lead of the Hindenburg and of Pan American in its trans-Pacific endeavor.

Why Use Cowl Flaps

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Presented at the Long Range Seaplane and Airship Problems Session, Fifth Annual Meeting, I. Ae. S. January 27, 1937

THIS paper refers to the adjustable type of cowl flaps, controllable from the cockpit, as used on the trailing edge of the N.A.C.A. type of radial engine cowling. Although these cowl flaps have been employed extensively, both in this country and in Europe (Plates 1, 2, 3 and 4) there still seems to be a considerable difference of opinion in the industry as to the desirability of using them. It appears to be the feeling among many designers that any advantage that may be gained through the use of cowl flaps is limited to the case of unbaffled engines, and that in the case of engines of high specific output, equipped with the conventional pressure type of baffle, the improvement in cooling or performance through the use of cowl flaps is negligible.

This misunderstanding exists but the reason for it is not entirely clear since considerable test data have been published,[1,2] which show that cowl flaps are not only effective in improving the performance of aircraft, but that in many cases their use is necessary in order to realize the full advantage of the modern high-powered engine.

During the past year additional tests have been conducted on radial engine cowls by the N.A.C.A. and by the United Aircraft Corporation which, due to improved methods of presentation and a clearer understanding of engine cooling and cowl drag, afford conclusive data on the efficacy of cowl flaps. The purpose of this paper is to analyze these new data and to show that the use of cowl flaps accomplishes the desirable end of providing adequate cooling at all air speeds, including ground running, and at the same time limits the drag due to cooling at maximum speed to the minimum attainable with the conventional type of N.A.C.A. cowl.

The N.A.C.A. has, as a result of theoretical analysis checked by actual tests, arrived at a fundamental criterion which clarifies the phenomena accompanying the cooling of finned cylinders to a point where it can be applied in an easily understandable form. The cooling (*i.e.*, cylinder temperature) for a given engine-baffle-cowl combination is a function of the mass flow of air passing the cooling surfaces. The mass flow of air for constant density and air temperature is a direct function of the air-pressure drop across the cooling surfaces, or, as normally measured, the difference in pressure between the front and the rear of the engine cylinders. This leads to a very important axiom which is fundamental to the problem of engine cooling: *for a given engine-baffle combination operating under a fixed set of conditions,*[3] *one definite pressure drop is required to maintain a prescribed value of cylinder temperature;* that is, regardless of whether the engine is operating in a climb, at high speed, or whether the pressure drop is accomplished by means of a blower or by the forward velocity of the airplane, the pressure drop must be the same if the same prescribed cylinder temperature is to be obtained in every case.

The above axiom can be used to show the advantage that can be realized through the use of cowl flaps. If the relationship between pressure drop and airplane speed is examined and, given engine-baffle-cowl combination is assumed, it is evident that the pressure drop across the cylinders, and therefore the cylinder temperatures, will not be the same for the engine operating on the ground, in a climb and at high speed, because the velocity of the air approaching the cowl varies. It has been shown that the pressure drop across the engine varies very closely as the square of the velocity of the air approaching the engine cowl. At climbing speed, for example, the pressure drop across the cylinders with a fixed cowl is only about 35 per cent of what it is at high speed. In other words, if the power of the engine remains constant, as it does with a constant speed propeller, the cooling of the engine will be good at high speed and poor during climb. In fact, if the cowl is designed to limit the drag due to cooling at high speed; that is, to allow the cylinder temperatures to reach their maximum prescribed values at high speed, the engine will badly overheat in climb. This is of course due to the greatly reduced pressure drop across the cylinders at climbing speed.

If, on a given cowl arrangement, it is found, by flight test, that the engine fails to meet the prescribed cooling requirements during climb, it is evident that the pressure drop across the cylinders is too low and must be increased. This can be done by enlarging the air exit opening at the gill, as by cutting off the skirt, increasing

[1] Beisel, MacClain and Thomas, *The Cowling and Cooling of Radial Air-Cooled Aircraft Engines*, S.A.E. Journal, Vol. 34, No. 5, May, 1934.

[2] Shoemaker, Rhines and Sargent, *Further Progress in Controlled Cooling of Radial Aircraft Engines*, S.A.E. Journal, Vol. 37, No. 4, October, 1935.

[3] Constant air temperature, air density, engine power, r.p.m. and mixture ratio.

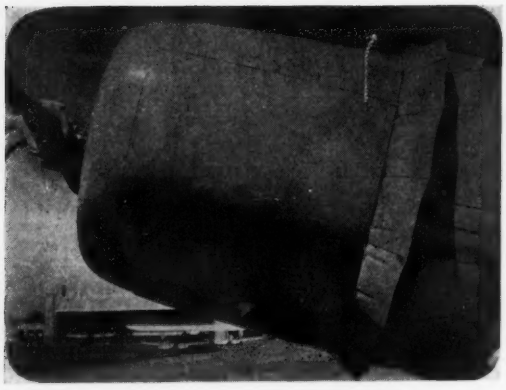

PLATE 1. Cowl flaps used on Vought XSB2U-1 airplane. Flaps open.

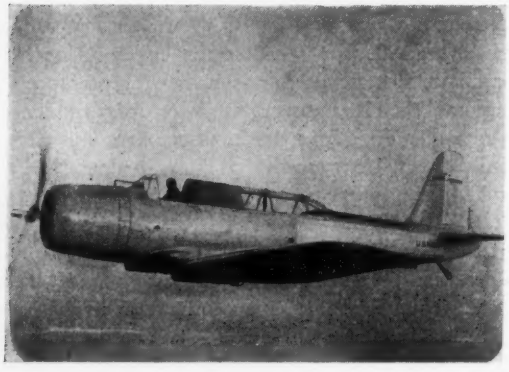

PLATE 2. Vought XSB2U-1 airplane in flight. Cowl flaps closed.

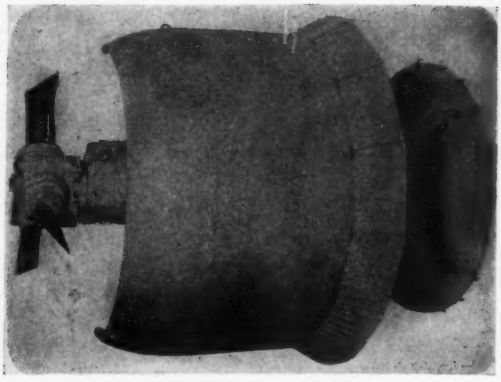

PLATE 3. Cowl flap installation supplied by Gnome Rhone (French).

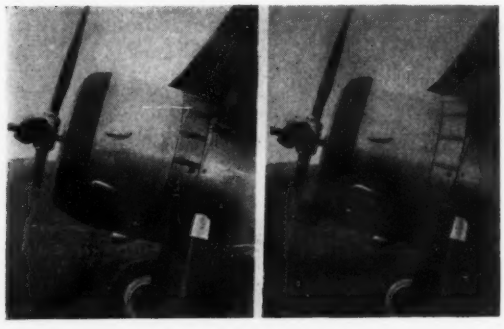

PLATE 4. Cowl flap installation supplied by Bristol (British). Flaps shown open and closed.

the cowl skirt diameter, or by flaring the skirt. Any one of these methods of increasing the pressure drop across the cylinders, in the case of a fixed cowl, may provide the necessary engine cooling at climbing speeds, but will, at the same time, not only provide more than the required cooling at top speed, but, as is to be shown later, also very materially increase the airplane drag at high speed as compared with the original cowl designed only for the high speed condition.

It will be of interest to compare the cooling effectiveness and the aerodynamic resistance of various cowl shapes. The N.A.C.A. has recently conducted hundreds of tests to obtain such values. Since the engine temperature is a function of the pressure drop across the cylinders, this latter value can be used as a measure of cooling effectiveness. It is desirable, however, for the sake of convenience in comparing the various cowls, to consider the pressure drop in terms of the dynamic head resulting from the velocity of the air approaching the cowl. The dynamic head ordinarily designated by the symbol q is equal to $\frac{1}{2}\ \rho V^2$, where ρ is the mass density of the air and V is the airspeed. The deviation of the pressure from the static pressure at any point on an aerodynamic body is proportional to q, provided the effect of scale, that is of Reynolds number, is negligible. That the scale effect on the pressure differences measured in cowling tests is negligible, is shown by the fact that the measured pressures have been found to vary substantially with the square of the velocity, as has been mentioned above. If the pressure drop through the baffles is designated by the symbol ΔP, the non-dimensional ratio $\Delta P/q$ becomes a convenient measure of the ability of a given cowl form to cause a flow of cooling air through a given engine-baffle-combination. Other things equal, the volume of flow will be proportional to the square root of this ratio.

Considerable light has been thrown on the relationship between cowl drag and cooling air pressure drop by experiments recently conducted by the N.A.C.A. on a nacelle of conventional shape, fitted with a Wasp 9-cylinder radial engine having pressure baffles, enclosed in various N.A.C.A. cowls representing a considerable range of nose and skirt shapes. The shapes tested are shown in Figs. 1a and 1b. Fig. 2 shows curves of $\Delta P/q$ against the drag coefficient C_D based on engine frontal area. The points presented here do not cover the entire scope of the tests, but are restricted to the results obtained from cowlings of more or less

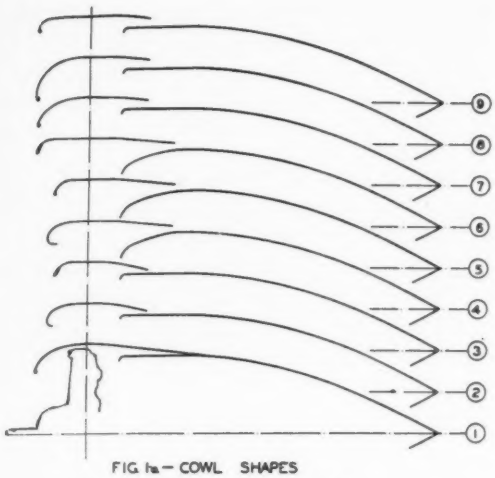

FIG. 1a — COWL SHAPES

NUMBERS CORRESPOND TO NUMBERS ON FIG. 2

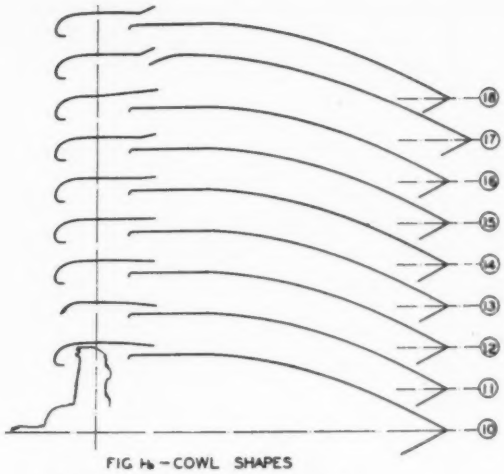

FIG. 1b — COWL SHAPES

NUMBERS CORRESPOND TO NUMBERS ON FIG. 2

conventional shape. The four points marked with an "X" on the extreme right of curve "A" are for cowl flaps. The values of $\Delta P/q$ are not as high as might be expected if the shape of the inner cowl had been pulled in so as to reduce the "choking" effect on the flow at this point with flaps fully extended.

The test curves "A" and "B" correspond to baffle conductivity coefficients, represented by the symbol K, of .0424 and .0909 respectively. The conductivity coefficient is in effect an orifice coefficient based on engine frontal area. Its magnitude is dependent on the leakage area between the cylinder wall and baffles and therefore varies with fin depth and spacing, and baffle tightness. It is defined by the expression $Q = K\ (\Delta P/q)^{1/2} SV$.
where

Q = Volume flow of cooling air.
$\Delta P/q$ = Ratio of pressure drop across engine to dynamic pressure.
S = Area of engine disc.
V = Airplane speed.

The actual value of K for current production Pratt & Whitney single-row engines with normal finning and conventional baffles is about .060, and for the two-row engines from 0.13 to 0.18. Three of the test points in Fig. 1, represented by squares, were actually measured at $K = .060$, and will be seen to be approximately on curve "A", which can be assumed to be representative of and at least conservative for the single-row engine. The curves for values of K appreciably higher than .0424 can be expected to lie to the right of curve "A", as is shown by the curve for $K = .0909$. The curves for deep finned single-row and two-row engines would be expected to lie somewhat farther to the right than curve "B".

The connection between Fig. 2 and the subject of this paper is as follows: For a given engine baffle combination, a particular cowl shape corresponds to a definite point on the curve. In order to obtain a higher value of $\Delta P/q$, it is necessary to alter the cowl shape, and to accept the increase in drag coefficient indicated by the general shape of the curves, since the tests in question, as well as those reported in references 1 and 2 show that for engineering purposes *a given value of $\Delta P/q$ corresponds to a definite value of the drag coefficient for practically any cowling of good conventional design.* Although the curves of Fig. 2 show only a few points for the cowl flaps and for a cowl not adaptable to the effective use of cowl flaps, from the tests of references 1 and 2 it can be expected that a good conventional cowl with a smoothly faired skirt equipped with adjustable cowl flaps will give points of $\Delta P/q$ and C_D that will either lie directly on the curves of Fig. 2 or will show slightly lower values of C_D for the corresponding values of $\Delta P/q$. The only known practicable means of altering the cowl shape, and hence the value of $\Delta P/q$, in flight, is the cowl flap. It may be well to point out that a sliding cowl skirt, as a means of varying the gill opening, would accomplish the same end, with the exception, however, that the maximum pressure drop obtainable by such a mechanism would be appreciably lower than through the use of cowl flaps. Obviously a sliding cowl skirt, that would provide a large variation in gill opening, constitutes a rather impractical design problem.

In order to estimate the effect of cowl flaps on airplane performance, calculate the top speed of a transport airplane, of modern design, under two sets of conditions: (a) with a fixed cowl designed to cool the engine in climb, and (b) with a flapped cowl, designed for adequate cooling in level flight with flaps closed, and in climb with flaps open.

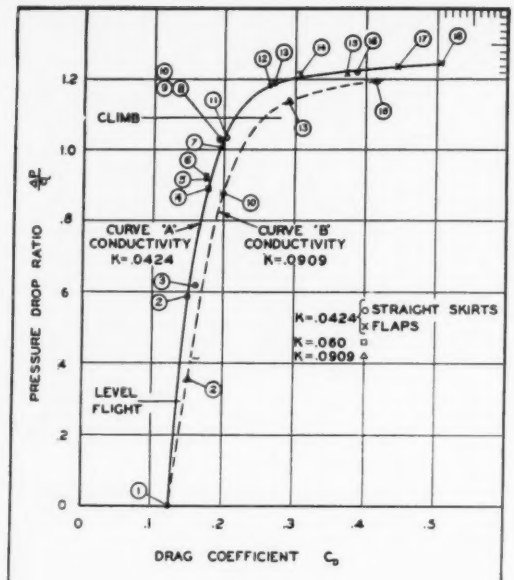

FIG. 2
RELATION BETWEEN COOLING AIR PRESSURE DROP AND NACELLE DRAG

The following assumptions will be made:

Engines—2 Pratt & Whitney Wasps rated at 550 hp. at 8,000 feet.

True Climbing Airspeed at 8,000 feet—120 m.p.h.

Maximum Speed Level Flight for case (a) at 8,000 feet—230 m.p.h.

Propeller efficiency—80%.

Pressure drop through baffles required to cool engine at 8,000 feet—31.2 lbs./sq. ft. (6 inches of water).

The mass density under standard conditions at 8,000 feet is = .00187.

The dynamic head in climb at 120 m.p.h.

$p_{120} = \rho V^2/2 = 29.0$ lbs./sq. ft. (5.56 inches of water).

$\Delta P/q$ required in climb $= 6/5.56 = 1.08$.

The dynamic head in level flight at 230 m.p.h.

$p_{230} = 106.5$ lbs./sq. ft. (20.5 inches of water).

$\Delta P/q$ required in level flight $= 6/20.5 = 0.293$.

The points corresponding to these values of P are noted on curve "A". The nacelle drag coefficient corresponding to the climb point is 0.215. This drag will apply to the climb condition for both cases (a) and (b), since it is necessary to provide adequate cooling in climb, and as previously mentioned a given value of $\Delta P/q$ is accompanied by a definite value of drag coefficient for any type of conventional cowl used. For case (a) this same drag coefficient must necessarily apply also to the level flight condition, since the shape of the cowling is fixed. Incidentally, the fixed cowl will provide $20.5 \times 1.08/6 = 3.69$ times as much pressure drop as that required to cool in level flight. The pressure drop in level flight for case (b) can, however, by closing the flaps, be reduced to the 6 inches of water required to cool, with a reduction of the nacelle drag coefficient to 0.135.

In order to determine the effect of this reduction in nacelle drag on airplane speed, the following is obtained from the foregoing assumptions:

Thrust horsepower (for two engines) $= 550 \times 2 \times .80 = 880$ hp.

Airplane drag in level flight, case (a) fixed cowl $= 880 \times 375/230 = 1{,}435$ lbs.

The diameter of the Wasp engine is $51\frac{7}{16}$ inches; its area is therefore 14.4 square feet.

The drag of the two nacelles in level flight for case (a) fixed cowl is thus $14.4 \times 2 \times 0.215 \times 106.5 = 660$ lbs.

The drag of the two nacelles in level flight at 230 m.p.h. for case (b) flapped cowl, on the other hand, is reduced to:

$$14.4 \times 2 \times 0.135 \times 106.5 = 415 \text{ lbs.}$$

Thus it is seen that the use of the cowl flaps results in a $[(1435 - 1190)/1435] = 17\%$ saving in power at the 230 mile speed, or an increase of approximately $[(1435/1190)^{\frac{1}{3}} - 1] \times 100 = 6.3\%$ or 14.5 m.p.h. in speed at full power. This calculation is slightly conservative, since the increase in speed results in a higher value of q, permitting a further slight reduction in the value of $\Delta P/q$ required to cool the engine and hence in the value of the drag coefficient.

The improvement in performance through the use of cowl flaps on a single-row engine provided with tight fitting baffles is clearly shown by the above calculations. There has been no controversy or misunderstanding regarding the value of cowl flaps on unbaffled engines with high values of K. There is general agreement on this point. However, the latest type of deep-finned engines and the two-row engines with large air flow space are known to have values of K between the low value for tight fitting baffles on shallow-finned single-row engines and the high values for engines with no baffles whatever. The curves of Fig. 2 show that the greater the value of K for a given engine, the greater must be the difference between drag coefficients C_D for climbing speed and high speed to give the same pressure drop and therefore the same cooling for the two flight conditions. It becomes quite clear then that cowl flaps are even more effective on deep-finned and on two-row engines ($K = .17$ approx.) than is indicated by the example where a 6.3% improvement in high speed is shown with the low value of $K = .06$.

The discussion so far has dealt with the results of full-scale wind-tunnel tests. It should be more interesting and the test results should be considered more conclusive if data taken from free-flight tests on an

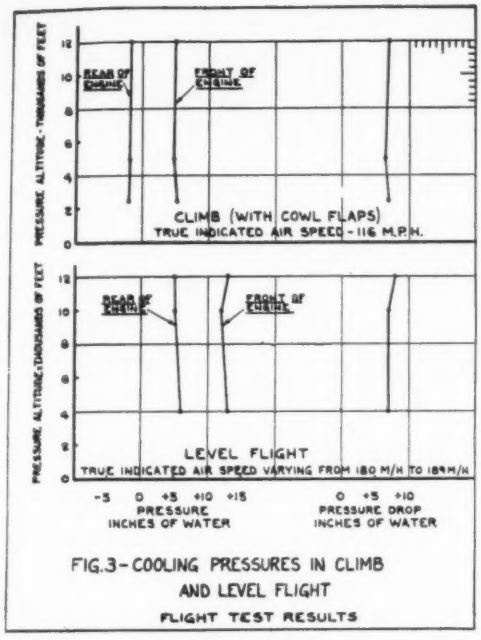

FIG. 3 - COOLING PRESSURES IN CLIMB AND LEVEL FLIGHT
FLIGHT TEST RESULTS

actual airplane are examined. Fig. 3 shows the cooling air pressures across the engine during cowl flap tests on a Pratt and Whitney 1535 engine for climb and for high speed. The engine was run at maximum prescribed horsepower and the greatest difference between power at a given altitude for level speed and for climb was 1%. The mixture ratio was automatically kept constant. In order to eliminate confusion, the upper curves show the cooling air pressures during climb with flaps open 25° and the lower curves during high speed with flaps closed. The latter condition gave a smooth contour line for the cowl skirt.

These curves clearly show the effectiveness of adjustable cowl flaps. Although the pressure in front of the engine for climb is much less than that for high speed, the effect of the open cowl flaps is to induce a negative pressure in the rear of the engine during the climb, resulting in a total pressure drop across the engine essentially the same for both climb and high speed. The average temperature of the cylinders clearly reflects this condition in that the temperatures in climb were only three to five degrees warmer than in level flight.

In order further to confirm the conclusions arrived at from the results of the full-scale wind-tunnel tests on cowling conducted by the N.A.C.A., as given in the earlier part of the paper, it appeared that it would be highly desirable to obtain comparative flight test data on a Wasp engine equipped with cowl flaps and also equipped with a fixed cowl. Fig. 4 shows the shape of the cowl, drawn to scale, with flaps closed, flaps open 30°, and with flaps removed (fixed opening).

Flights were made January 11th and 12th, 1937, with several cowl-flap positions and also with the flaps

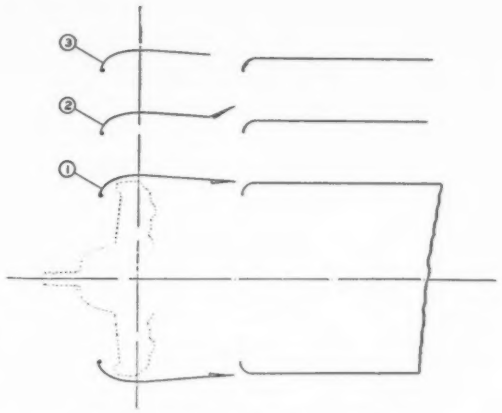

FIG. 4 - COWL SHAPES USED ON FLIGHT TEST OF V-50 AIRPLANE WITH SIHI-G WASP ENGINE

① COWL FLAPS CLOSED
② COWL FLAPS OPEN 30°
③ COWL FLAPS REMOVED

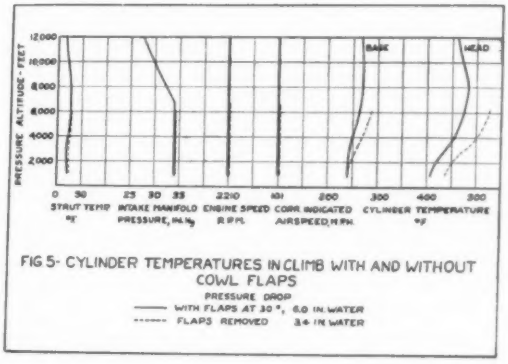

FIG. 5 - CYLINDER TEMPERATURES IN CLIMB WITH AND WITHOUT COWL FLAPS
PRESSURE DROP
—— WITH FLAPS AT 30°, 6.0 IN. WATER
------ FLAPS REMOVED 3.4 IN. WATER

removed, leaving a fixed gill opening of 9½ in., to obtain comparative operation in climb, level flight, and ground runs. The same power was used on all the flights as indicated by constant manifold pressure, constant carburetor-air temperature, and constant engine speed. The level-flight runs were made at strut temperatures of 31–34°F. and pressure altitudes near 6,600 feet, to maintain a constant air density.

Climbs were made with a corrected indicated speed of 101 m.p.h. automatic carburetor in mid-position (constant mixture strength) full throttle, carburetor air at 70°F., engine speed governed to 2,210 r.p.m. Previous to climbing, the temperatures of the engine were allowed to stabilize in level flight at 1,000 feet. At intervals of 1,000 feet during the climbs readings were taken of the temperatures of No. 3 head and base (known from previous tests to be maximum), manifold pressure, and strut temperature. The climbs were continued in the case of the open flap set at 30° until the cylinder base temperature had reached a maximum and started to drop, or, in the case of no flap, until the cylinder head temperature had reached the maximum allowable of 525°F. and with no indication of

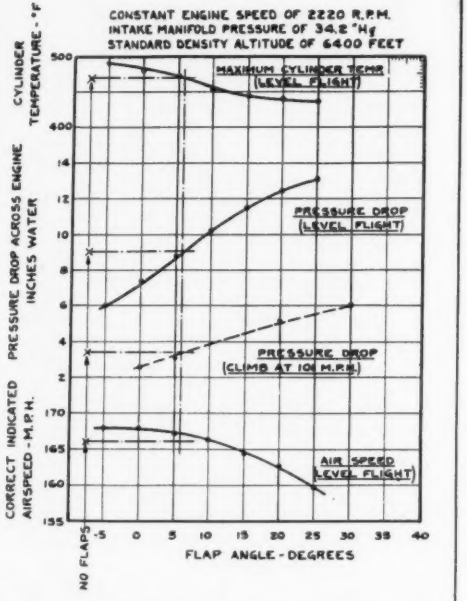
CONSTANT ENGINE SPEED OF 2220 R.P.M.
INTAKE MANIFOLD PRESSURE OF 34.2 "Hg
STANDARD DENSITY ALTITUDE OF 6400 FEET
CYLINDER TEMPERATURE - °F
MAXIMUM CYLINDER TEMP (LEVEL FLIGHT)
PRESSURE DROP ACROSS ENGINE INCHES WATER
PRESSURE DROP (LEVEL FLIGHT)
PRESSURE DROP (CLIMB AT 100 M.P.H.)
CORRECT INDICATED AIRSPEED - M.P.H.
AIR SPEED (LEVEL FLIGHT)
NO FLAPS
FLAP ANGLE - DEGREES

FIG. 6 - TEMPERATURE, PRESSURE DROPS AND AIRSPEED VERSUS FLAP ANGLE

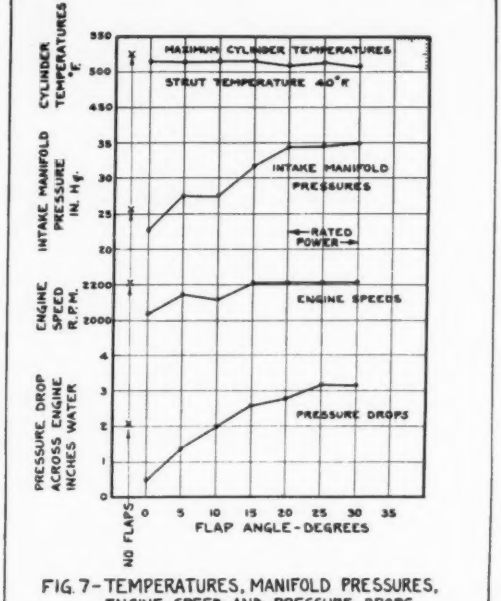

FIG. 7 - TEMPERATURES, MANIFOLD PRESSURES, ENGINE SPEED AND PRESSURE DROPS VERSUS FLAP ANGLE GROUND RUNS

stabilizing. Fig. 5 shows the results of these climb tests. It will be noted that the pressure drop across the engine, with flaps open, is 6 inches of water, approximately the amount necessary to cool a Wasp engine in flight. The pressure drop, however, with the flaps removed (fixed opening) was only 3.4 inches of water, clearly accounting for the higher cylinder temperatures. It is obvious that a more drastic change in the cowl skirt shape than shown on cowl 3 of Fig. 4 is necessary to provide adequate cooling in climb when using a fixed gill opening.

Level flight runs were made at a temperature-altitude combination to give a standard density altitude of 6,400 feet or an airspeed correction factor of 1.10. The air was very smooth and quite consistent results were obtained. Engine speed, manifold pressure, carburetor air temperature, and density altitude were carefully checked and adjusted for each change in flap angle. The runs were started with the cowl flaps at 25° and successive runs made by closing the flaps 5° at a time. The tests without flaps were flown within three hours of the tests with flaps and atmospheric conditions were practically the same.

The curves of Fig. 6 show the effect of cowl flap opening on cylinder temperatures, pressure drop, and air speed. The points "X" on the left side of the figure represent the corresponding test results for the flap removed (fixed opening) condition.

The decrease in cylinder temperatures, the increase in pressure drop and the decrease in air speed as the flap angle is increased are clearly indicated. The dotted curve shows the pressure drops obtainable in climb for different flap angles. In order to obtain a pressure drop of 6 inches of water required to cool the Wasp engine, the flap must be opened to 25° or 30°. The fixed cowl, that is, with flaps removed, although apparently providing a large gill opening, was entirely inadequate in providing cooling in climb, as shown by the cylinder temperatures and pressure drops in climb, Figs. 5 and 6. However, the value of cowl flaps in being able to duplicate the results obtained with a given fixed cowl is clearly shown, that is, the fixed cowl gave an identical cylinder temperature, pressure drop (high speed as well as climb) and practically identical high speed as did the cowl flaps when opened some 6°. It is indicated that the use of an equivalent fixed cowl giving the same cooling in climb as can be obtained with cowl flaps will result in a maximum air speed eight to ten m.p.h. lower than that obtained with the flaps closed.

A comparison of the maximum cylinder temperature in climb with flaps open, Fig. 5, and that obtained at high speed with flaps closed, Fig. 6, shows practically identical values. This of course should be true since the pressure drop across the engine is in both cases 6 inches of water.

The ground runs were started with open flaps with the engine operating at rated power and speed. After the cylinder temperatures had stabilized, it was found

that the cowl flaps could be closed to a 20° setting, without reducing the engine power, and at the same time maintain the cylinder head temperatures below the allowable limit of 525°F. In fact, the engine was run for 32 minutes at rated power. For smaller flap openings it was necessary to reduce the engine power, as indicated by the curves of manifold pressure and engine speed, as shown on Fig. 7, to maintain the same cylinder temperatures. The decrease in pressure drop as the flap is closed and the superiority of the cowl flaps over the fixed gill opening (flap removed) is again apparent.

Book Reviews

Handbuch der Luftfahrt, edited by RICHARD SCHULZ, G. W. FEUCHTER AND WERNER V. LANGSDORFF; J. F. Lehmanns Verlag, München, 1936; 413 pages, Mk. 6.

The stability and extent of an industry is usually indicated by the handbooks, year books and directories that show its scope. Shipping and aviation have certain similarities, as the types of their units are so much alike in all countries that comparisons are available. Furthermore, ships and aircraft have an international interest beyond any other form of transportation as they are to be seen in all parts of the world. Therefore, warships, yachts and aircraft lend themselves particularly well to classification.

When a new international year book on aviation appears it should be welcomed as another indication of the broadening interest that is being taken in aircraft by the group that can only make use of a reference work in its own language.

This new handbook is an attempt to do for German readers what "All the World's Aircraft" has done for English readers for many years. Making too specific comparisons between the two works would not be generous as the authors of the new handbooks have made an excellent start. The 570 illustrations and sketches give a comprehensive idea of the types of aircraft and aircraft engines in use in many countries.

The first part of the book is devoted to facts about the air forces, civil aircraft, airports and aeronautical press of the leading aeronautical countries. The second and third parts give detailed descriptions and performance characteristics of hundreds of airplanes and engines.

When the German Air Ministry sponsors the publication of any book there is a natural anticipation of finding it to be a comprehensive volume prepared with great thoroughness. This should be particularly true of an annual which covers the field of international aviation. When a reader opens this new handbook he naturally turns to the section dealing with German aviation, expecting to find information that is new and of a kind that annuals, published by other nations, do not contain. When he finds in the section of military airplanes descriptions of aircraft of all the other leading countries and nothing about German military airplanes there is created a feeling of disappointment. When he finds the size of the officers and enlisted personnel and budgets of other leading countries given in great detail and finds the same facts regarding the German Air Force omitted an unprejudiced reader wonders why such facts are withheld. Probably the authors and the German Air Ministry felt that the development and organization of German military aviation had not reached a point where such disclosures could be made without giving an incorrect impression. As this work will certainly be followed by succeeding volumes the hope may be expressed that these deficiencies may be overcome in the *next issue.*

The authors should receive the appreciation of all those who require sources of information regarding aviation for this addition to the reference shelf in their libraries.

Air Power and Armies, by J. C. SLESSOR; Oxford University Press, London, 1936; 231 pages, ill., $4.00.

Since the Great War many books have been written which have explored the strategic and tactical use of aircraft in warfare. This book limits its scope to the cooperation of air forces with land forces, although it discusses freely the use of naval aviation and independent air forces.

After defining the object of an airforce in a land campaign the author discusses the apparent divergence between the war aims of an army and of an air force. He shows how air forces are independent of lines of communication and have no flanks; that they are not committed to any one course of action, but can switch almost at a moment's notice from one objective to another several hundred miles away.

Great emphasis is given to the necessity of maintaining the offensive in air warfare. This can be gained by bombing the vital centers of the enemy and securing control of the air through the operation of pursuit and attack aircraft.

What the author terms the supplementary offensive is the destruction or neutralization of enemy air forces through joint action of bombers and fighters. He gives the results achieved by the British and the French along the front lines in 1917 and warns of the danger of underrating possible effects of bombing on aerodromes.

Chapters on Strategic Concentration, Fighting Troops and Supply, Air Attack on Communication, and a study of the Battle of Amiens form a basis for his conclusions which are generally grouped under the heading The Third Revolution. Crediting the invention of gunpowder and the introduction of the machine guns with the two first great revolutionary events in warfare he then states the reasons for his belief that the conquest of the air will have a similarly important effect. Air power will bring an end to the great concentration of troops such as occurred in the last war owing to the effect it will have on the maintenance of modern armies which have heretofore been able to keep their lines of communication and supply open. He draws a discouraging picture of warfare in a theatre of action which relies on a single line of supply such as Siberia or Manchuria with only the Trans-Siberian railway for their connection with European Russia. No longer will it be possible to mobilize strategic concentration of armies or navies. The railway and transport systems will be destroyed or so badly crippled by air attack that armies will have to rely more on motor transport than in the past.

The author concludes that in the next war those in command will have to rely on mobility for concentration of land forces rather than trenches.

Land and air operations of the future must be deliberately planned together to get the best results from each other and the plan of campaign on the ground, whether in attack or defense, may be profoundly influenced by the air factor.

The book will be a valued addition to the all too few treatises on air strategy and tactics.

LESTER D. GARDNER

The Need for Empirical Data for the Design of Aircraft Structures

JOSEPH S. NEWELL, *Massachusetts Institute of Technology*

Presented at the Structural Problems in Aircraft Design Session, Fifth Annual Meeting, I. Ae. S. January 27, 1937

PROGRESS in any art requires that current practice and previous experience be reviewed at intervals so that the reasons for the success of certain procedures and the failure of others may be determined. In a young art the reasons may not always be established correctly but theories may be developed and new processes worked out to be checked by subsequent experience. Without such theories it is hopeless to attempt extrapolation or expansion so that progress must be limited to interpolation or to improvement of detail within a circumscribed field of action. Such limited progress is undesirable in an art as young as the design of aircraft structures, but it is equally undesirable that too rapid progress be made by using theories or procedures which are based on reasoning alone, with no background of experience to justify such assumptions as may be made. Rationalization of processes should keep abreast of experience, theories should keep abreast of test data but where life is at stake, as it is in an improperly designed structure, dependence should not be placed upon theories which have not been checked, in part at least, by empirical data.

While it is obvious that inanimate materials cannot develop reasoning powers so that they may appreciate and conform to the assumptions made by the designing engineer, this point appears to be overlooked frequently and structures are often expected to conform with assumptions or conditions which simplify the solution of mathematical equations rather than with the natural limitations of the materials themselves. The results are, of course, disappointing, sometimes because the structure is unsafe, sometimes because it is unduly heavy. Consider, briefly, some of these results by comparing actual test data with the indications of theory.

A plot of the readily available data on the crushing strength of corrugated aluminum alloy sheet, 17 ST, 24 ST, and alclad of the 24SRT alloy, yields the curves shown in Fig. 1. The 24 ST alloy, with its higher yield point, develops a higher crushing stress than the 17 ST and the test values lie practically on the same curve as the 24 ST alclad.

The third curve in the figure represents the expression for the critical stress given on page 382 of Timoshenko's *"Theory of Elastic Stability,"* with coefficients based on the standard corrugation having a pitch to depth ratio of 3.33. The expression, originally

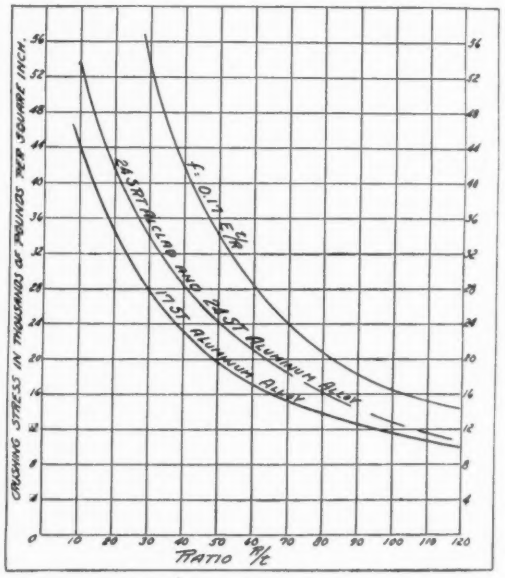

FIG. 1. Corrugated Aluminum alloy. Crushing stress parallel to corrugations.

developed by E. Seydel in Jahrbuch 1930 der deutschen Versuchsanstalt fur Luftfahrt, is written,

$$f = \frac{2\pi^2}{b^2 t}\left(\sqrt{D_1 D_2} + D_3\right) \qquad (1)$$

where

- b represents the length of half wave of the buckled sheet, here taken as equal to the pitch of corrugation;
- t represents the thickness of the sheet;
- D_1, D_2 and D_3 are stiffness factors parallel and perpendicular to the corrugations.

These stiffness factors depend on the shape of the corrugations, radius of curvature, and so on, and when the properties of the standard corrugation are used, Eq. (1) reduces to $f = 0.17\ Et/R$ where E is the modulus of elasticity of the material, t its thickness and R the radius of the corrugation. It is to be noted that this equation represents a curve having the same shape as the empirical curves but it indicates a much higher crushing stress than the test data. A reasonable approximation to the empirical curve for 17 ST is $f = 0.11\ Et/R$, so the theoretical curve is about 50 per cent too high. Furthermore, it indicates that the crushing

TABLE 1.

P/d	*Theoretical* C	*Empirical* C
2.0	1.45	1.10
2.5	1.20	1.04
3.0	1.04	1.01
3.33	1.00	1.00
4.0	0.98	0.98
4.5	0.96	0.96
5.0	0.94	0.94
5.5	0.92	0.92
6.0	0.89	0.89

stress varies only with E and t/R, for a given shape of corrugation, while the curves for 17 ST and 24 ST having the same values of E and t/R, show that some other factor affects the strength.

The available theory appears, therefore, to be of no value to designers in predicting the strength of corrugated sheet in compression. As it stands it leads to dangerously high values for the crushing stress and, though certain corrections can be made on the basis of test data, the resulting expression does not provide for the effect of all the variables.

The test data available on stainless steel and the aluminum alloys lead to the development of the partly rational, partly empirical formula which follows.

$$f = C \times 34000 \sqrt{\frac{E \times f_{y.p.}}{10^7 \times 34000}} \left(\text{Log}\frac{200t}{R}\right) \qquad (2)$$

In Eq. (2) E represents the modulus of elasticity of the material, $f_{y.p.}$ its yield point, t its thickness and R the radius of the corrugation used. For the standard corrugation whose pitch depth ratio is 3⅓, and whose pitch-radius ratio is 3.55, the value of the coefficient, C, is 1.0. For other pitch-depth ratios, values of C have been obtained from a transformation of Seydel's equation using the appropriate values of D_1, D_2 and D_3, and have also been back-figured from very meager test data. The resulting values are compared in Table 1.

On the basis of the available data the formula is in good accord with tests but the data are too few to be conclusive. The indications are that the flatter sections, those having pitch-depth ratios greater than 3, behave about as would be expected from the change in their stiffness factors. The sections having pitch-depth ratios less than 3 are not as strong as the theory would indicate, there being a marked reduction in the strength of the "circular" corrugations having a pitch-depth ratio of two.

When corrugated sheet in shear is considered there is no apparent agreement between theory and test results, at least on the basis of the formula on page 384 of Timoshenko's "*Theory of Elastic Stability*" and the data in Wright Field Memo., A.D.M. 1203. Fig. 2 shows comparative curves and indicates that where

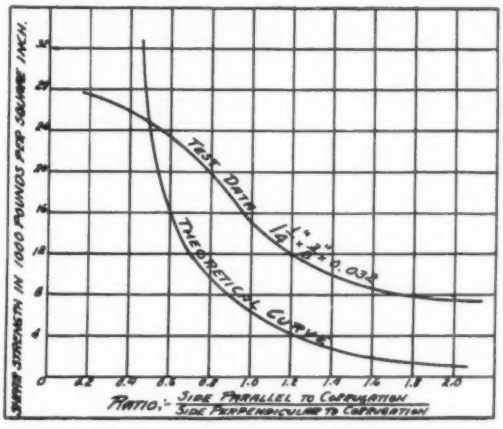
SHEAR STRENGTH IN 1000 POUNDS PER SQUARE INCH.
TEST DATA
THEORETICAL CURVE
RATIO:- SIDE PARALLEL TO CORRUGATION / SIDE PERPENDICULAR TO CORRUGATION

FIG. 2. Corrugated Aluminum alloy. Shear stress parallel to corrugations.

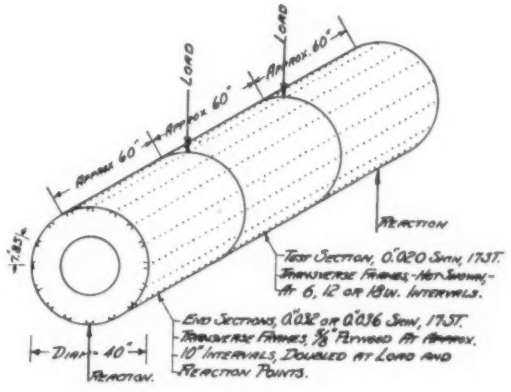
LOAD
APPROX. 60"
REACTION
TEST SECTION, 0.020 SHTH, 17ST.
TRANSVERSE FRAMES, HAT SHAPED, AT 6, 12 OR 18 IN. INTERVALS.
END SECTIONS, 0.032 OR 0.036 SHTH, 17ST.
TRANSVERSE FRAMES, ¾" PLYWOOD AT APPROX. 10" INTERVALS, DOUBLED AT LOAD AND REACTION POINTS.
DIAM. 40"

FIG. 3.

theory conforms approximately to a hyperbolic curve, some of the tests lie on a reversed curve having a shape very similar to the combination of Johnson and Euler curves used for columns. The data readily available are insufficient to permit the development of a working formula for maximum stress on corrugated sheet in shear, but they are adequate to warn the designing engineer that his unverified theoretical values are dangerous in some regions, unnecessarily conservative in others.

The tests on forty-inch diameter, circular cylinders made at the Massachusetts Institute of Technology have shown similar discrepancies between actual stress distributions and those obtained by the conventional beam theory which has been justified by a century of use in bridge and building construction. The most stressed fiber on a cylinder of the dimensions and loading shown in Fig. 3 is not always that most distant from the neutral axis but may be anywhere within 30° or 45° of the plane of loading. Fig. 4 shows typical distributions obtained from strain gage readings on cylinders in which very stiff transverse frames were spaced at 6, 12 or 18-inch intervals. For the 6-inch spacing the cross-section remained circular be-

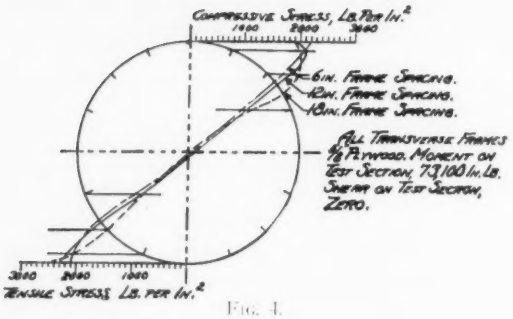

Fig. 4.

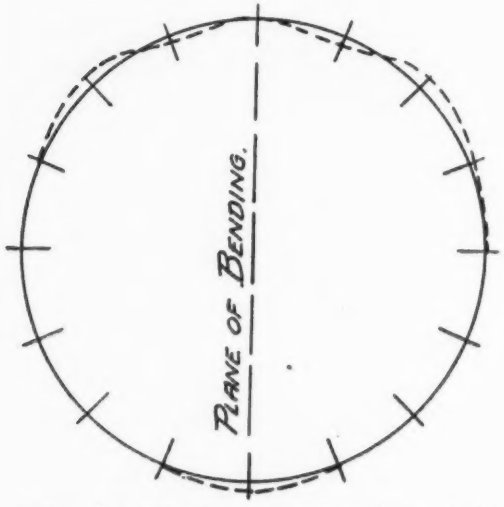

Fig. 5. Distortion of 40-inch cylinder between frames of ⅝ inch plywood spaced 18 inches apart when the cylinder carries bending only.

Table 2

Transverse Frame	I* of Frame	Moment** at Ultimate Load Inch-Pounds
⅝ Plywood	"Infinite"	352 000
B	0.0217	332 000
C	0.00491	329 000
D	0.000977	337 000

* Moment of Inertia about centroid of section. I of longitudinal stiffeners, 0.0017 in.⁴

** This is the moment throughout the section between loads, Fig. 3, the section having zero shear for conditions of test.

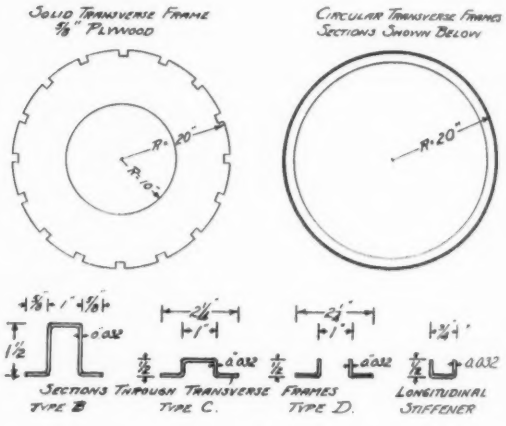

Fig. 6.

tween frames and the maximum compressive stress occurred at the stiffener in the plane of the load, as the theory indicated it should. For the 12 and 18-inch spacing the stiffeners deflected between transverse members distorting the cross-section somewhat as shown in Fig. 5. The stress distribution was materially altered, as indicated in Fig. 4.

The modification in stress distribution indicates that the conventional beam theory is not directly applicable in all cases to beams such as these cylinders, but it is difficult with the meager data in hand to separate cause from effect. It may be that incipient buckling of the skin due to shear or compressive stresses is responsible for the distortion of these cylinders, or it may be that the longitudinal stiffeners tend to buckle between transverse frames, thus relieving themselves of some load and distorting the section. Whether the skin stresses cause the stiffeners to bend or the stiffeners the skin is not immediately apparent but the result, in any case, is to produce a marked redistribution of stress over the cross-sections between transverse frames. From such measurements as have been made the frame themselves appear to remain circular even though extremely light and flexible. Such distortion as occurs seems to be between frames and though it is small, from 0.03 to 0.06 inches, its effect is appreciable.

None of the mathematical analyses so far available appear to consider this sort of deformation with its modified stress distribution. Most of them are based on the minimum strain-energy principle and indicate that the stiffness of the transverse frames is of importance in determining the strength of a stiffened cylinder. The hypothesis of minimum strain-energy is doubtless correct, when applied so that all variables are provided for, but the results of tests on four cylinders having transverse frames of four sizes,—see Fig. 6,—but having everything else the same throughout appear to contradict the conclusions drawn from present applications of the method. From these tests it appears that the stiffness of the frames contributes little to the strength of the cylinder, since that having the very flexible frames of Fig. 6, type D, carried essentially the same bending moment as a similar cylinder having heavy plywood frames. The results, for the four cylinders having frames spaced 12 inches apart, are given in Table 2.

From the six circular cylinders so far tested at M.I.T.,

three having plywood transverse frames spaced at 6, 12 and 18-inch intervals and three having circular rings of varying stiffnesses spaced at 12-inch intervals, the following conclusions seem justified:

(1) The strength of a circular cylinder in bending depends upon the stiffness and strength of the longitudinal stiffeners, hence upon the distance between transverse members, but is essentially independent of the stiffness of the intermediate transverse frames, an intermediate frame being one which is not subjected to external concentrated loads.

(2) Within the limits of practical sizes for transverse frames, almost anything that will stand accidental or handling loads will prove adequate for the intermediate frames on circular cylinders and will suffice to break the longitudinal stiffeners up into a series of columns as well as to maintain the circular cross-section of the structure without distortion.

Further tests may show the above conclusions to be incorrect. It is dangerous to theorize on so few data, of course, but the results are of importance to designing engineers and they are published here to enlist the services of designers in procuring additional data so that they may be studied and a rational method of analysis obtained.

Slope of Lift Curve for Any Aspect Ratio

H. W. SIBERT, *University of Cincinnati*

(Received January 11, 1937)

IT is necessary to know the slope of the lift curve before the design load factor for an airplane can be found. The Department of Commerce gives the following formula for m, the slope of the lift curve at any aspect ratio R:

$$m = 4m_6/(3 + 6/R), \tag{1}$$

in which m_6 is the slope of the lift curve when $R=6$. Perhaps the easiest way to demonstrate that this equation is incorrect is to derive it and show upon what assumptions it is based.

It is well known that the relation between α, the angle of attack for any aspect ratio R, and α_∞, the angle of attack for $R=\infty$ which gives the same lift coefficient C_L as α does, is:

$$\alpha = \alpha_\infty + C_L/(\pi R), \tag{2}$$

in which α and α_∞ are measured in radians. Now let ΔC_L be the change in the lift coefficient corresponding to a change $\Delta\alpha$ or $\Delta\alpha_\infty$ in the angle of attack. Then from Eq. 2,

$$\begin{aligned}\Delta\alpha &= \Delta\alpha_\infty + \Delta C_L/(\pi R)\\ &= \Delta\alpha_\infty\,[1 + m_\infty/(\pi R)],\end{aligned} \tag{3}$$

in which $m_\infty = \Delta C_L/\Delta\alpha_\infty$ is the slope of the lift curve for $R=\infty$. To obtain Eq. 1, let $m_\infty = 2\pi$, which is an approximate result obtained from thin-airfoil theory. Then Eq. 3 becomes

$$\Delta\alpha = \Delta\alpha_\infty(1 + 2/R). \tag{4}$$

If $m = \Delta C_L/\Delta\alpha$ is the slope of the lift curve for any aspect ratio, m is found by dividing the equality $\Delta C_L = \Delta C_L$ by Eq. 4, which gives

$$m = m_\infty/(1 + 2/R). \tag{5}$$

To be consistent, m_∞ should now be replaced by 2π in Eq. 5. But this substitution would not produce Eq. 1. Instead let $R=6$ in Eq. 5 and obtain

$$m_\infty = 4m_6/3 \tag{6}$$

Eq. 1 results from substituting this value of m_∞ in Eq. 5.

Certain inconsistencies in the derivation of Eq. 1 are now evident. For example, 2π was substituted for m_∞ in Eq. 3 but not in Eq. 5. Instead, m_∞ was replaced by $4m_6/3$, which is approximately 5.6 for most airfoils because m_6 is usually in the neighborhood of 4.2.

Actually, there is no necessity of assuming a value for m_∞ in Eq. 3. Suppose the equality $\Delta C_L = \Delta C_L$ is divided by Eq. 3. This gives

$$m = m_\infty/[1 + m_\infty/(\pi R)] \tag{7}$$

The result of letting $R=6$ in Eq. 7 is

$$m_6 = m_\infty/[1 + m_\infty/(6\pi)] \tag{8}$$

This equation can be solved for m_∞ to yield

$$m_\infty = m_6/[1 - m_6/(6\pi)] \tag{9}$$

When this value of m_∞ is put in Eq. 7, the result is

$$m = m_6/(1 + Km_6/\pi), \tag{10}$$

in which

$$K = 1/R - 1/6 \tag{11}$$

Note that Eq. 10 is not based on any assumption as to the value of m_∞. In fact, no inconsistent assumptions whatsoever are involved in its derivation. Hence Eq. 10 instead of Eq. 1 gives the correct value of the slope of the lift curve.

Graphical Solution for Continuous Beams—A Supplement

LEO KIRSTE, *Blériot-Aeronautique, Suresnes (Seine)*

(Received February 1, 1937)

IN the May 1936 issue of this Journal, the author has shown how the possibility of separating "bay moments" and "support moments" leads to a graphical method for computing the latter. The following indications will contribute to make this method much more practical.

For continuous girders, it is preferable to consider the deflection, y, rather than the bending moment; thus, the condition of continuity is obtained directly and need not be computed from moment areas. The differential equation is of the same type

$$-y'' = M/EI + Py/EI = k^2\,(M/P + y),$$

where M means the "pure bending" moment, including given support moments, if any.

Instead of solving this equation by successive approximations, the final values of y can be obtained directly by the method of "fixed points." With the end condition $y = 0$ for $x = 0$, the above equation represents a sheaf of curves having the property that all tangents, for a given value of x, go through the same point. These "fixed points" can be found graphically, as shown by Fig. 1.

Starting with the abscissa of a known fixed point F_n, join to point A, the abscissa of which is x, and its ordinate equal to unity. From this straight line, carry the quantity $(k\Delta x)^2$ up (for tension) or down (for compression). Joining A with B gives the abscissa of F_{n+1}. Point F_{n+1} itself lies on the straight line $\overline{F_nB}$, point B having the abscissa x and the ordinate M/P.

Obviously, the upper part of the graph is independent of M and does not have to be retraced, when modifying the given moment distribution.

The fixed point F_0 is in the origin of the deflection curve; Fig. 2 shows how to find the following, one after the other. Element 11–12 and the entire deflection curve may then be drawn by going back to the origin.

In compressed beams, the locus of the fixed points may go to infinity (between station 3 and 4 in Fig. 2) and come back on the other side. This means that a critical value has been reached, which, for constant k, would be equal to Euler's load $\pi^2\,EI/4x^2$. At x corresponding to twice this value (station 7/8) the locus curve has a double point; the deflection curve must go through it and its curvature there has the constant value $y'' = -k^2\,(M/P + f)$.

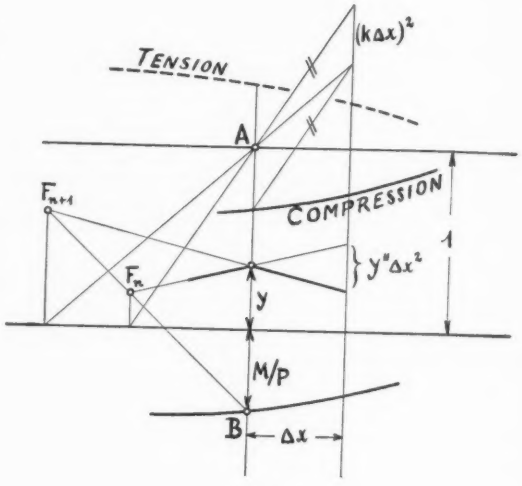

FIG. 1.

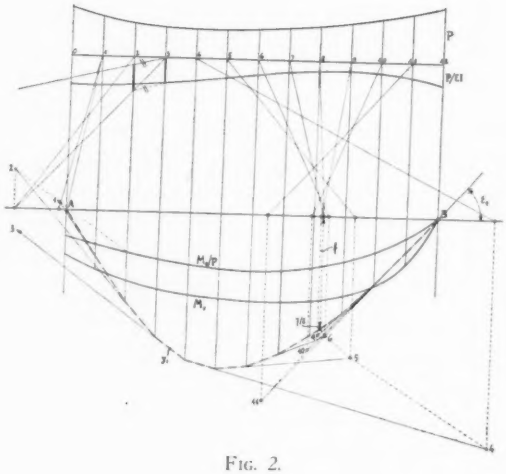

FIG. 2.

There is always a possible solution for the deflection curve, even in the case of compression loads far above the critical, but "stable" solutions are only those where the sense of the deflection is mainly in the sense of the side load, so that the strain energy of the bent beam may be furnished by the sinking side load. For "unstable" solutions, the beam would have to be bent previously in the opposite sense.

In a continuous beam, first draw the y-line corresponding to the end supports alone (Fig. 2). For any

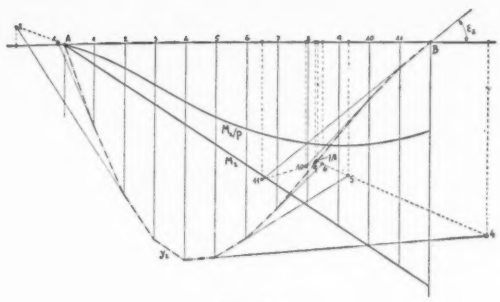

FIG. 3.

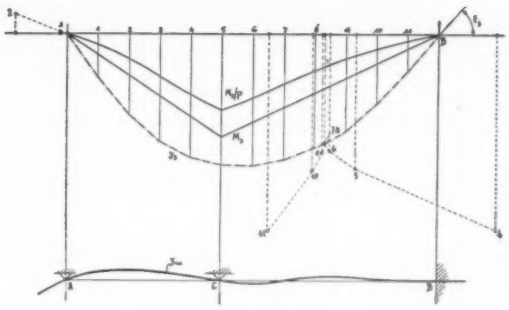

FIG. 4.

intermediate support, or a fixing moment, draw another y-line corresponding to a triangular moment distribution (Figs. 3 and 4), the final magnitude of which is found by combining the deflections, or rotations, and equalizing their sum to zero at the considered points, *e.g.*

$$y_c = y_1 + M'_2/M_2 \cdot y_2 + M'_3/M_3 \cdot y_3 = 0$$

$$E_B = E_1 + M'_2/M_2 \cdot E_2 + M_3'/M_3 \cdot E_3 = 0$$

The resulting bending moment in the beam is

$$M_{res.} = M_1 + M'_2 + M'_3 + P \cdot y_{res.}$$

It is a great advantage of the described method to be able to ascertain, without the need of mathematical investigation, whether stable combinations of a given moment distribution and additional support, or fixing moments are possible or not. Moreover, the influence of shifting an intermediary support, modifying the given moment distribution, etc. is readily shown.

Book Reviews

The Wonder Book of the Air, by C. B. ALLEN AND LAUREN D. LYMAN; The John C. Winston Company, Philadelphia, Pa.; 340 pages, ill., $2.50.

When two experienced writers such as C. B. Allen and Lauren D. Lyman collaborate in preparing a book on aviation for the general public the inevitable result could have been none other than an accurate and interesting story of flight. Both of these aviation editors have followed the happenings in aeronautics for so many years that they are able to evaluate events, appraise personalities and present a panorama of the wonders of the air which makes fascinating reading to the old timer as well as to the novice.

It is a gift book *par excellence* for youngsters who wish to learn of the historical background as well as the leading events in the art which they are exploring through the construction of model airplanes. They will be taken on air journeys over some of the famous air tracks of the world. Famous pilots and their exploits are presented by men who "covered" the events when they were in the making. The technicalities of flight are written in simple language so that they are understandable to youth and to layman. The places the airplane, the balloon, the airship, and the glider occupy in aviation are all explained so that the purposes and advantages of each will be clearly understood.

Radio, aircraft instruments, the air mail, women in aviation, military and naval aviation, all find their places in the book. Explanations of some of the new slang of the air and a brief chronology conclude the text. Added to the authoritative contents are illustrations appearing on nearly every page which have been selected with great discrimination.

LESTER D. GARDNER

Advance in the Air, by F. V. MONK AND H. T. WINTER; Blackie & Son Limited, London and Glasgow; 223 pages, ill., 3s.6d.

For British youth who wish to believe that England leads the world in aviation this book is excellent reading. To those with a broader viewpoint it gives the impression of overlooking some of the achievements of other countries. While the authors give full credit to the metal clad airship, the Armstrong seadromes and to Agello's great speed record, there is a background of pardonable national pride which detracts somewhat from the value of the book to readers who do not live in England.

The authors give a graphic account of the England-Australia air race and then turn to short chapters on actual as well as experimental advances in aeronautics. They peer into the future possibilities of the steam engine, metalclad wooden propellers and giant flying boats. They explore the stratosphere, land in fog and describe Engish de-icing equipment.

Books which are clearly written to stimulate the imagination of young men should not be subjected to the critical attention given technical works. Judged by this standard the book is a worth while effort.

The Computation of the Lift Distribution Over the Span

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Presented at the General Aerodynamics Session, Fifth Annual Meeting, I. Ae. S. January 28, 1937

THE distribution of the lift over the span of a monoplane wing is of technical interest in structural and aerodynamical studies.

The determination of a wing shape giving rise to a given or assumed lift distribution can be based on the evaluation of a self contained mathematical expression. The evaluation itself must generally follow approximate methods. The inverse problem, where the wing shape is given or assumed, and the lift distribution is to be determined, cannot so easily be reduced to a self contained mathematical expression. It is solved by assuming a fairly reasonable solution, checking the same by determining the corresponding wing shape and correcting the first assumed lift distribution in the light of the discrepancies discovered. This is the ordinary engineering method of solving intricate problems, where the ease of obtaining the answer but not the elegance of the mathematical treatment counts.

The problem is thus reduced to the determination of a wing shape corresponding to a given lift distribution. More specifically, the distribution of the angle of attack is determined. This makes it necessary to know the effective angle of attack at each station of the span, as distinguished from the geometrical angle of attack apparent from mere inspection of the wing. The difference between the two is the induced downwash. The determination of the downwash called into play by a given lift distribution is the gist of the problem.

This work can be taken out of the hands of the professional mathematicians, and reduced to the application of common engineering mathematics, by taking into consideration that the mathematical exactness of the method need not exceed the exactness of the broad step taken. For in successive approximations, all errors are corrected equally in later and more refined steps, regardless of whether they originate from the errors in the original assumption, or from the coarseness of the mathematical method used.

Such reduction is obtained by starting the computation with a suitable elliptic lift distribution. This is the simplest case indeed, for then the downwash at all points of the span is the same. The downwash angle is

$$\frac{L}{\rho V^2/2 \qquad b^2\pi} \tag{1}$$

where the symbols have their usual meaning.

In the vertical plane of the span, as much air must move up as moves down. Accordingly, out and sideway of the span, along the points of the extended span, there is an induced upwash. That upwash is not constant, but fades out gradually at larger distance from the wing, approaching proportionality to the inverse of the square of the distance from the wing. Just beyond the tip, the law is more involved. For the first interval equal to the span, the average upwash angle is about .4142 of the constant downwash angle. For the second such station, it is .0353, for the third 0.166 and for the fourth it is eight tenths of a per cent. These figures are obtained from the consideration of the stream function of the two-dimensional flow caused by the lateral motion of a straight line in a perfect fluid. Along the extended span, that stream function is represented by the function

$$\sqrt{x^2 - 1} - x$$

Substitute $x = 1, 3, 5, 7$ etc. into that expression and form the differences between consecutive values.

That upwash is of some interest for the analysis of airplanes flying side by side, or in formation, or of birds flying in formation. That same upwash can now also be directly used for the computation of the downwash caused by any lift distribution. For the relations just outlined do not only hold for the wing in toto, they also hold for any portion of the wing into which the same may be assumed to be divided. The span is preferably divided into a number of equal parts, for instance ten or twenty. Every such portion experiences then its own downwash, as given by Eq. (1), and furthermore the upwash given above as fractions of these downwashes dependent on the distance. With twenty portions, for instance, the downwash at any one station is theoretically equal to the downwash of that interval, minus 41.42% of the downwash of the adjacent intervals, minus 3.53% of the downwash of the next adjacent intervals, etc. For all intervals, theoretically 400 contributions have to be determined in this really simple manner. Actually, the number is much smaller, as the influence of the more distant intervals is negligible, and the problem is generally simplified by symmetry.

It is thus seen that the entire involved relation hinges about a number of universal constants, which converge rapidly toward zero, so that four are probably enough for engineering needs. Different values from those given above may serve even better; the best values must be determined by suitable research. The general method is pointed out here in principle, the best numerical values have still to be determined.

Sphere Tests in the N.A.C.A. 8-Foot High-Speed Tunnel

RUSSELL G. ROBINSON, *National Advisory Committee for Aeronautics*

Presented at the General Aerodynamics Session, Fifth Annual Meeting, I. Ae. S. January 28, 1937

SPHERE tests were raised from the status of mere academic interest to the important duty of indicating the amount of turbulence in an air stream when it was discovered how sensitive to turbulence is the flow pattern, and hence drag, of a sphere. Their use became essential with the further discovery that initial turbulence in an air stream could alter the aerodynamic characteristics of wind-tunnel models, notably the maximum lift of airfoils, as greatly as a large change in scale. It is necessary to know the turbulence of test air streams and sphere tests are now an accepted part of the calibration program of a new wind tunnel.

The results of such sphere tests in the new N.A.C.A. 8-foot high-speed tunnel are interesting in showing to what degree the turbulence in a wind tunnel may be reduced, in evaluating approximately the effectiveness of the tunnel entrance cone in securing low turbulence, and in comparing the totally different action of spheres at very high speeds.

The fluid mechanics that accounts for the variation in sphere characteristics with changes in Reynolds Number and turbulence is treated at length elsewhere.[1] It is sufficient here to recall that the critical Reynolds Number of a sphere in an air stream is the Reynolds Number at which the drag coefficient C_D passes through the value 0.3 in changing from a higher value to a much lower value with increasing speed and that the less the turbulence of the air the higher the value of the critical Reynolds Number.

Fig. 1 indicates: (1) the critical Reynolds Numbers for several N.A.C.A. wind tunnels—the variable-density, the 7- by 10-foot, and the full-scale tunnels; (2) the highest average critical Reynolds Number obtained in other tunnels—that of the California Institute of Technology; and (3) the value for free air, 385,000, obtained by flight measurements and towing in still air at Langley Field.[2]

The limiting values shown in this figure correspond to turbulence of about 1.8 per cent for the N.A.C.A. variable-density tunnel and about 0.3 per cent for free air, the percentage expressing the root mean square

FIG. 1. Critical Reynolds Numbers.

of the average speed fluctuations compared to the mean velocity of flow.[3]

The N.A.C.A. 8-foot high-speed tunnel is a Göttingen-type, single-return, closed-throat wind tunnel of circular section throughout. One of the design aims was low turbulence because it is comparatively easy to increase the turbulence of an air stream at any time but difficult, if not impossible, to reduce it. Great advantage would lie with an air stream of free-air turbulence. To this end every care was used to eliminate turbulence-producing elements from the tunnel design and to suppress the inevitable turbulence by allowing an appreciable length of passage upstream of the entrance cone in which the turbulent wake of the last set of guide vanes might decay and by providing a large contraction ratio of 9 (24-foot diameter to 8-foot diameter) in the entrance cone.

It should be pointed out that the critical Reynolds Numbers were determined by the pressure method as suggested by Dryden instead of by the drag method, because the former is much easier to use. In this system the difference in pressure ΔP between the front stagnation point and the rear portion of the sphere is measured and, when divided by the dynamic pressure q, the resulting pressure ratio $\Delta P/q$ is found to vary with Reynolds Number much the same as does the drag coefficient. It has been determined experimentally[4] that a pressure ratio $\Delta P/q = 1.22$ is equivalent to a drag coefficient of 0.3 and this ratio is indicated in the figures for determining the critical Reynolds Numbers. The method of support, accuracy, and finish of the spheres was in accordance with best present-day practice.

[1] See H. L. Dryden and A. M. Kuethe, *Effect of Turbulence in Wind Tunnel Measurements*, N.A.C.A., T. R. No. 342.

[2] Robert C. Platt, *Turbulence Factors of N.A.C.A. Wind Tunnels as Determined by Sphere Tests*, N.A.C.A., T. R. No. 558.

[3] C. B. Millikan and A. L. Klein, *The Effect of Turbulence*, Aircraft Engineering, August 1933, pp. 169–174.

[4] See reference given as footnote 2.

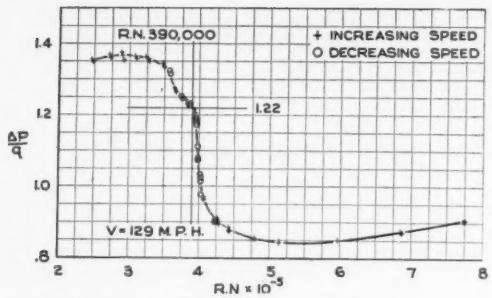

FIG. 2. 4-inch sphere at center of testing plane.

Fig. 2 shows the experimental points and curve for a 4-inch sphere at the center of the testing plane in the 8-foot high-speed tunnel, 4½ feet downstream from the end of the entrance cone. The value 390,000 for the critical Reynolds Number is greater than any value yet recorded for a wind tunnel and is, in fact, higher than the value that has been determined for free air by about the precision of previous tests. The previous N.A.C.A. tests indicated that smaller spheres will produce higher critical Reynolds Numbers if there is considerable turbulence, but low-turbulence tests have indicated no effect of sphere size so the high value can hardly be ascribed to the size of sphere used. As shown by the small amount of scatter of the experimental points, control of the testing conditions was nearly ideal. The extreme stability of flow at any speed, as illustrated by the single curve defined by the test points, whether the speed was being increased or decreased, is surprising in view of the radical flow changes that take place with very small speed increments. Within a certain range the change is so rapid that not only the drag coefficient but the *total drag* decreases with an increase of speed.

Fig. 3 shows the faired curves for the 4-inch sphere in the testing plane at radii of 2½ and 3 feet from the center of the jet. The critical Reynolds Numbers for these off-center positions average 370,000. The average critical Reynolds Number over the working portion of the jet may then be taken as 380,000 and the resulting turbulence factor as unity, indicating a turbulence equivalent to that of free air.

It will be noted that the critical Reynolds Number for the 4-inch sphere occurs at an air speed of 129 m.p.h. In an attempt to measure the turbulence at a higher air speed a 2-inch sphere was mounted on the center line of the tunnel but, as shown in Fig. 3, the pressure ratio failed to drop at any speed up to 500 m.p.h. Had the 2-inch sphere indicated the same turbulence as the 4-inch sphere, the critical Reynolds Number would have occurred at 274 m.p.h., or at 36 per cent of the velocity of sound. Note that the sphere does not show a marked increase of pressure at 500 m.p.h. These same phenomena were observed when the 2-inch sphere was tested in the N.A.C.A. 24-inch high-speed tunnel at which time it was suggested that

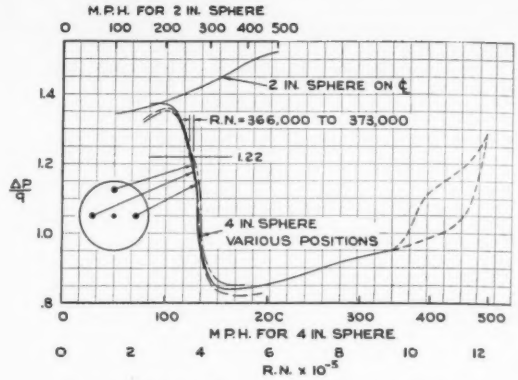

FIG. 3. 2-inch and 4-inch spheres in testing plane.

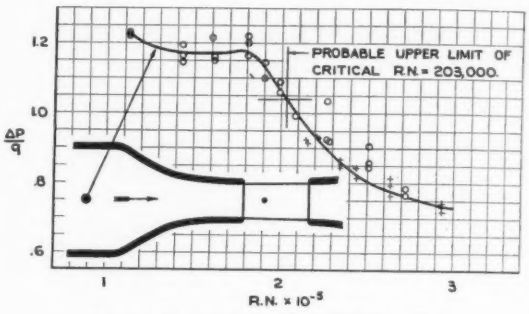

FIG. 4. 12-inch sphere in entrance cone.

the failure to obtain a critical Reynolds Number might be ascribed to the effects of compressibility in delaying the onset of boundary-layer turbulence. If this effect is responsible, it occurs with local velocities over the sphere of 1.5 × 274 or 410 m.p.h., or less. These speeds represent a new low for serious compressibility effects and might indicate early compressibility effects on small, bluntly shaped parts of aircraft. No other explanation has been found. In order to determine the effect of compressibility on a sphere that has already passed through its critical flow and is exhibiting its low-drag characteristics, the 4-inch sphere was tested at speeds up to 500 m.p.h. The results are presented in Fig. 3. These results are about what would be expected: a slowly rising coefficient (pressure ratio) from 150 to about 400 m.p.h., then a more rapid increase to 500 m.p.h. at which time the maximum local velocity over the sphere must be approximately sonic. The variation of characteristics above 400 m.p.h. is shown by the two dashed extensions to the curve above that speed. Compressibility apparently affects the high-drag, large-wake condition at lower air speeds than it does the low-drag, small-wake condition. The low-drag flow pattern, however, shows more effect when the maximum local velocities are near sonic.

In an effort to determine quantitatively the reduction of turbulence through the entrance cone, a sphere was mounted in the large, low-speed end of the entrance cone as shown in Fig. 4. A 12-inch sphere was used

to permit reasonable tunnel speeds. Unfortunately the only convenient mounting position was found to be in a field of converging flow which indicates a favorable pressure gradient. The effects of this pressure gradient appear in the results of Fig. 4 as a lower pressure ratio, or drag, in all flow conditions, probably because the separation point is farther aft, with the favorable pressure gradient, for all values of Reynolds Number. This change may be considered as a downward shift of the curve and, if the critical pressure is likewise adjusted downward ($\Delta P/q = 1.04$) so that it indicates about the same rate of change of flow conditions, an approximate critical Reynolds Number is obtained. It is felt that this value represents a probable upper limit to the critical Reynolds Number because after the first adjustment is made the sphere in a favorable pressure gradient acts similarly to a spheroid elongated in the direction of flow and such a spheroid has a higher critical Reynolds Number than does a sphere. These operations are admittedly only approximate but it is probably safe to say that the critical Reynolds Number in the entrance cone is no more than 203,000 so that the turbulence reduction has been from at least 1.0 per cent to about 0.3 per cent.

In conclusion then it may be stated that sphere tests in the N.A.C.A. 8-foot high-speed tunnel have shown free-air turbulence for that tunnel, have checked previous results indicating that spheres cannot be used to evaluate turbulence in air streams above about 270 m.p.h. and shown how differently compressibility acts on the two different conditions of flow about a sphere, and have revealed that an area reduction of 9:1 in an entrance cone may be accompanied by a turbulence reduction from at least 1.0 per cent to about 0.3 per cent.

Elastic Behavior of Box Beams

BURDELL L. SPRINGER, *University of Michigan*

Presented at the Structural Problems in Aircraft Design Session, Fifth Annual Meeting, I. Ae. S. January 27, 1937

Introduction

MANY studies have been made of the elastic behavior of the structure of airplane wings and a number of theories have been advanced as a result of these studies. In general, however, it may be said that too little attention has been directed in these studies to the properties of the shear webs and their relative importance in defining the elastic properties of the structure. It was with this end in view that the investigation described in this paper was undertaken. Tests were made at the University of Michigan of several aluminum alloy box beams having dissimilar front and rear shear webs, and the results have been compared with those obtained by theory. These tests were conducted with the cooperation of the National Advisory Committee for Aeronautics and are presented here by the permission of that Committee.

At the present time designers using the elastic axis method for the stress analysis of their wing beams are unable to predict accurately the exact location of this factor. Full-scale tests are frequently necessary to establish its position. It was found that an accurate prediction of the elastic properties of a simple rectangular box beam can be made. Theoretical results are in error principally due to a limited knowledge of the shear deflection characteristics of the webs. The influence and importance of additional knowledge concerning the shear webs themselves is definitely shown.

Theoretical Considerations

When speaking of the elastic properties of a box beam, the author has in mind its elastic reaction to applied loads. A heterogeneous distribution of loading normal to the plane of the wing creates a complex distortion which when analyzed sectionally becomes fundamentally a rotation and a direct beam deflection. To simplify the problem it is necessary to reduce this information still further and consider the effect of simple concentrated beam loads and torsional moments. The relationship between such elementary examples and actual distributed load can be established subsequently by the principle of superposition.

The elastic energy theory has been utilized in the following analysis of the box beam. The constant section of a rectangular box beam has been studied and several equations describing the elastic properties of such cantilevered beams are proposed. It will be noted that each of these equations contains terms involving the properties of the webs of the box. In such cases the inclusion of a "shear deflection factor" based on individual tests of each web demonstrates good agreement with experiment.

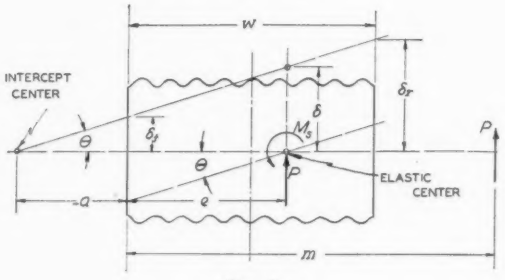

FIG. 1.

Angle of Twist

By considering the energy stored in the cantilevered box beam of Fig. 1, due to the torsional moment M_s applied in the plane of the tip bulkhead of the box, the following general equation of the angle of twist θ, radians, of the beam is obtained.

$$\theta = (1.3w/2th^2 + 2K_{vf} + 2K_{vr})\, M_s l/Ew^2 \quad (1)$$

where

w = Box beam width.
l = Distance from root of section considered.
h = Box beam depth.
t = Thickness of flange corrugations.
K_{vf} = Theoretical web energy constant,—front web.
K_{vr} = Theoretical web energy constant,—rear web.
E = Young's Modulus.

Results obtained by the use of Eq. (1) are shown to be considerably in error when compared with the measured angle of twist of the beam, Table 1. The major reason for this discrepancy is due to incorrect web energy constants. A slight modification of Eq. (1) was proposed and the true experimentally determined shear energy constants for each web of the box are used. The following equation proved to give better results.

$$\theta = (1.3w/2th^2 + 2K_{sf}\, K_{vf} + 2K_{sr}\, K_{vr})\, M_s/Ew^2 \quad (2)$$

TABLE 1
Angle of Twist of Box Beams-Tip Station

Beam	Experimental $\theta / M_s/Ew^2$	Calculated $\theta / M_s/Ew^2$		
		Energy Method	Modified Energy Method	Shear Deflection Method
B-21	3960	4450	3602	5520
B-23	2940	3588	2312	2840
B-24	2840	3118	2200	2640
B-25	2600	2460	2340	2880
B-26	2730	2374	2300	2820
B-27	3040	2460	2558	3380
B-28	2700	2374	2202	2640
B-29	3060	2608	2390	3040
B-210	2880	2608	2504	3240
B-45	2020	1956	1894	1760
B-46	2010	1870	1854	1680

where

K_{sf} = Shear deflection factor,—front web.
K_{sr} = Shear deflection factor,—rear web.

A second method for determining the angle of twist of a box beam involves the actual deflections of the front and rear webs. This method will be defined, Angle of Twist—Shear Deflection Method.

$$\Theta = (k_{sf} + k_{sr})M_s l/2Ew^2 \qquad (3)$$

where

k_{sf} = Experimental shear stiffness constant—front web.
k_{sr} = Experimental shear stiffness constant—rear web.

The development of Eq. (3) is based on the assumption that the walls of the box are in pure shear when a torsion is applied. The geometrical relationship between the angular deformation of a section and the vertical displacement of the webs under the action of the shearing stresses is the basis for the development of this equation. Table 1 contains the results obtained by the use of this method. Compared with the energy equation, the shear deflection method appears to give better agreement in general.

Elastic Center

P. Kuhn defines the elastic center of a beam in terms of two other basic "centers"; namely, torsional center and flexural center.[1] These centers designate the location of the point of rotation of a section of the box when a pure torsional and a pure bending load are applied respectively to the beam. When the torsional and flexural centers coincide that point is termed the elastic center. All tests of the several box beams described in this paper demonstrated that these centers did coincide, and it would then be proper to use this definition of elastic center.

By considering the simple case of pure torque applied to the tip station of the beam, Fig. 1, and assuming the various walls of the box to distribute the resulting shear stresses according to the accepted theory then the following equation can be derived for calculating the position of the elastic center.

$$e/w = k_{sf}/(k_{sf} + k_{sr}) \qquad (4)$$

In Eq. (4), e/w is the location of the elastic center

[1] P. Kuhn, *Remarks on the Elastic Axis of Shell Wings*, T.N. No. 562, N.A.C.A., 1936.

TABLE 2
Shear Web Constants

Web No.	Type	Designation Symbol	Web Thickness	Theoretical Web Energy Factor K_r	Theoretical Shear Stiffness Const. k_s	Exper. Shear Stiffness Constant k_s	Shear Defl. Factor K_s
1	Truss	T-20	0.020″	27.6	234.0	190	0.81
2	Truss	T-32	0.032″	17.2	147.0	101	0.69
3	Flanged Hole	F-20	0.020″	16.9	134.0	49.8	0.37
4	Flanged Hole	F-32	0.032″	11.0	87.5	38.8	0.44
5	Horizontal Corrugation	C_H-12	0.012″	2.7	21.5	52.5	2.44
6	Horizontal Corrugation	C_H-20	0.020″	1.6	13.1	49.0	3.75
7	Vertical Corrugations	C_V-12	0.012″	2.7	21.5	74.4	3.45
8	Vertical Corrugations	C_V-20	0.020″	1.6	13.1	38.3	2.99
9	Diagonal Tension	W-1	0.011″	4.6	38.2	60.8	1.59
10	Diagonal Tension	W-2	0.011″	4.6	38.2	71.7	1.90

TABLE 3
Elastic Center of Beams
Theoretical and Experimental

Beam	Experimental e/w			Theoretical e/w
	40 in. Station	30 in. Station	20 in. Station	All Stations
B-21	0.36	0.34	0.34	0.347
B-23	.68	.66	.64	.670
B-24	.74	.73	.72	.722
B-25	.69	.69	.65	.658
B-26	.72	.71	.68	.673
B-27	.60	.59	.57	.575
B-28	.73	.71	.70	.724
B-29	.66	.65	.65	.625
B-210	.64	.63	.63	.585
B-45	.46	.44	.40	.425
B-46	.48	.47	.44	.441

expressed as a fraction of the width of the box beam and measured from the front web. k_{sf} and k_{sr} are the experimentally determined shear stiffness factors for the front and rear webs, respectively. (Table 2.) Results obtained by means of Eq. (4) are given in Table 3.

It must be noted that when applying this method assurance must be had that the web stiffness factors in shear are independent of the magnitude of the load. Conditions of this nature are frequently encountered in the stiffened skin type of construction. In such instances progressive instability effects of thin elements in compression are likely to occur. A specific application of this method, however, can be made if particular values of k_s are obtained for loads of a magnitude equal to those used in the design condition.

Intercept Center

An unfamiliar term will be introduced here to describe a second point of rotation of the box beam under stress. When any combination of torsion and beam loading is applied to a bulkhead of the box beam each section of the beam rotates about a point in the plane of the section called the intercept center, Fig. 1. This point of rotation is quite apparently related to the angle of twist as well as to the elastic center of the station. This relationship is,

$$a/w = e/w - \delta/w\theta \qquad (5)$$

where:

a/w = Intercept center measured from front web expressed as a fraction of the beam width.

δ = Net deflection of beam at the section considered.

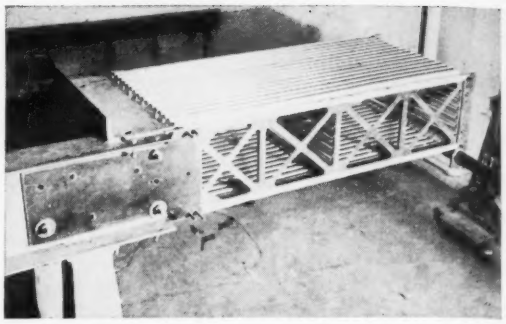

FIG. 2. Box beams showing method of mounting shear web.

When Eq. (5) is applied to the particular box beam shown in Fig. 1, and loaded as described by a single load P in the plane of the tip bulkhead, the following equation results.

$$a/w = e/w\ [1 - (2 - 2e/w + l^2/3k_{sf}I)/(m/w - e/w)] \qquad (6)$$

where:

l = Distance from root to station.

I = Moment of inertia of box beam.

m = Location of load P from front web in plane of tip bulkhead.

Results obtained from Eq. (6) for one beam are shown in Fig. 4.

DESCRIPTION OF TESTS

In substantiation of the foregoing theoretical results, tests were made of a box beam in which shear webs of different types could be used. A section of a box beam was cantilevered from a test jig. Beams were constructed of 17ST aluminum alloy and were 40 inches long, 20 inches wide, and 10 inches deep, Fig. 2. Flanges and bulkheads were made of 0.012 corrugations and were riveted together. Each of the ten different shear webs used in this study was mounted in turn in the box and fastened in place by self-tapping screws. Interchangeability and ease of fabrication was accomplished in this way. Of the forty-five possible web combinations available only twelve were used.

Loads were applied to the beam in the plane of the tip bulkhead by means of a screw jack mounted on the platform of a scale. A transverse loading bar, Fig. 3, attached to the beam made it possible to obtain different ratios of bending to torsional loads. The point of application of the load could be varied at will along the loading bar. Gages mounted above the test beam gave the deflections of the beam at various stations along the span. These deflections were used in calculating the deformations of the box under stress.

In these tests three types of loads were employed. Beams were tested in pure bending, pure torsion, and combined bending and torsion. In all cases the measured deflections were plotted as a function of the load. This procedure would indicate the presence

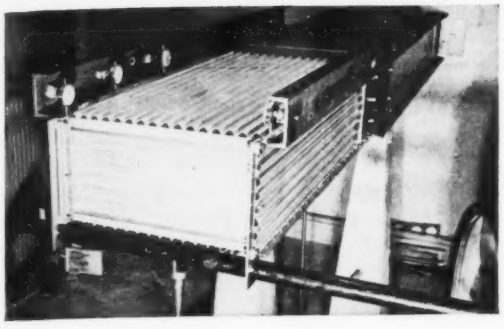

Fig. 3. End view of cantilever box beam showing loading device and gages.

of progressive or abrupt stress distribution changes in the box as the test load increased. In all cases a linear load-deflection curve was the result.

Test Results

A comparison of the results of these tests with those obtained theoretically shows good agreement. This is particularly true when comparisons are made with theoretical computations involving the shear deflections of the webs. As previously stated, shear factors for each web were determined prior to the beam tests. The use of these factors make possible an accurate prediction of the deflection as a whole of the box beams of which they are a part. Table 2 contains a description of each web, its theoretical shear stiffness constants. and the experimental shear deflection factor.

The angle of twist of several box beams measured at the tip station are given in Table 1. In referring to a particular beam it will be noted that the designation number for that beam indicates the webs used and their positions. For example, beam B-25 indicates a box beam in which No. 2 is the front and No. 5 the rear web. Theoretical values of θ, Eqs. (1), (2), and (3) are likewise recorded in this same table. It is found that Eq. (3), Shear Deflection Method, gives the best general agreement.

The results of the tests for determination of the elastic centers of the box beams at various stations along the span are shown by Table 3. A comparison is made with theoretical results obtained from Eq. (4). It appears from this study that an accurate prediction of the elastic center is possible by this method.

A third property of interest when studying the box beam is its intercept center. This center by definition is the point of rotation of a section of a box when a combination of torsion and bending is used. The intercept center is shown in Fig. 4 and is expressed mathematically, Eq. (6), relative to the front web of the box. Tests were made of each box beam and the results were plotted as shown by Fig. 4. The

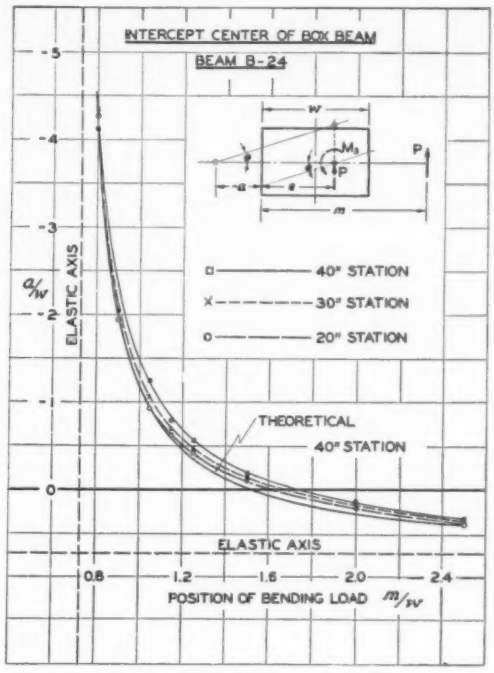

Fig. 4.

theoretical results are shown on this same curve. Only one box is shown here but all results were similar in nature and gave equally good agreement. An interesting observation to be made from Fig. 4 is that as the ratio of torsion to bending becomes large, $m/w = \infty$, the intercept center approaches the elastic center. On the other hand, as this same ratio approaches zero the intercept center is located farther and farther from the box.

Discussion

The results of theoretical calculations of the elastic behavior of a constant section box beam are in good agreement with experiment. It has been found that once the shear properties of the webs of the beam have been determined accurately all the properties of the box can be computed. The importance of this conclusion is that it appears that expensive tests of completed wing beam assemblies will not be required in order to establish their properties. Considerable investigation then should be directed toward the study of shear webs to establish methods for predicting their stiffnesses. The ultimate result of this would be to reduce required experimental work to a minimum.

The foregoing study has been confined to the limited case of a box beam having relatively stiff corrugated flanges. Further studies are under way at the present time in which the flanges of the box have been changed to stiffened skin. It is planned likewise to modify the setup to accommodate a tapered box, and a similar series of investigations will be performed.

Recent Advances in Airway Meteorological Service in the United States

D. M. LITTLE, *U. S. Weather Bureau*

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January 28, 1937

CONSIDERABLE progress has been made during the past two years in the expansion and intensification of the Weather Bureau airway meteorological service. The purpose of this paper is to review some of the salient features of the advances thus made and to outline briefly the development work now in progress.

The Air Commerce Act of 1926 provides that meteorological service for aviation shall be organized and maintained by the Weather Bureau. It is the responsibility of the Bureau of Air Commerce to provide other necessary aids to air navigation, including communications along civil airways in the United States. The backbone of an intensive meteorological service is communications and it is, therefore, highly important that the Weather Bureau and the Bureau of Air Commerce work closely together to provide a service which will meet the needs of the rapidly expanding air transport industry.

There are now over 700 weather reporting stations in the airway meteorological network, one-fifth of the number being operated by personnel of the Bureau of Air Commerce in conjunction with their communication activities. Weather Bureau supervising meteorologists periodically give instruction to Bureau of Air Commerce personnel in the taking of meteorological observations. Likewise, Weather Bureau stations, which have been established primarily for hourly weather reporting, perform communication work for the Bureau of Air Commerce and supervising personnel of that bureau give instructions in communication procedure to Weather Bureau personnel. At many points, particularly at intermediate airport terminals, the activities of the two bureaus have been consolidated and personnel of each bureau handle the routine work of the other bureau during scheduled periods of the day. This close cooperation between the two bureaus has resulted in a combined saving of well over $100,000, which was utilized in establishing additional stations. The consolidation of meteorological and communication work has eliminated, in large part, dual responsibility of employees and has provided more time for maintenance of radio and teletype aids by the Bureau of Air Commerce. Increased maintenance time at consolidated stations has already produced results as evidenced by the marked drop in the number of reports of inoperative radio-range, broadcast, and teletype facilities.

In this year's appropriations for the Weather Bureau, funds were provided to increase the number of reports from existing stations and to establish a large number of new weather reporting stations for airway service. In carrying out this program, arrangements were made to furnish two weather reports, an hour apart, from many "on-call' stations in order that airline operators might determine weather trends for clearing planes on routes over which hourly reports are not available by teletype or radio. Also, approximately 100 new 6-hourly weather reporting stations were established in regions where observations of this type were not heretofore available. Complete instrumental equipment, including mercurial barometers and barographs, was installed at each station. The barographs were of the latest open-scale type to permit the taking of accurate readings of 3-hourly barometric pressure change and characteristic, data which are essential to air mass and frontal analysis. The Weather Code was modified to permit the enciphering of more complete data, such as sky conditions, pressure change, clouds, ceiling, visibility and dewpoint. The reports as now coded contain sufficient data to satisfy the needs of all services of the bureau. All stations began using the code on January 1, 1937, and the newly established stations began reporting on January 15, 1937. With the increased density and completeness of observations, there should be a marked improvement in the analyses of weather conditions, as well as more accurate determinations of the rates of movement of windshift lines, fronts, etc.

To improve the technique of analyzing weather maps at the 52 Weather Bureau Airport Stations, a code was devised for use in transmitting by teletype and radio each day the "Air Mass and Frontal Analysis" ("AMAFA") of the 8 a.m., E.S.T., weather map as made in the Division of Meteorological Research of the Weather Bureau in Washington, D. C. The information contained in the daily message identifies the various air masses on the weather map and gives the location of their boundaries or fronts. With the 8 a.m. analysis as a basis, the Weather Bureau Airport Stations carry the analysis forward to succeeding 6-hourly maps.

Airlines have requested copies of the 6-hourly maps for use in their dispatch offices, to aid in planning

flight operations. Several years ago, it was the practice to transmit weather maps by teletype but the maps were necessarily crude, limited in area, and required an excessive amount of time on teletype circuits. With the number of weather reports rapidly increasing, it was necessary to eliminate the teletype maps and arrange to provide duplicate copies of 6-hourly manuscript maps. Machines for duplicating these large maps were installed at a number of important airport stations and excellent copies of weather maps are now available every six hours for use of airline operators.

Four additional airplane observation stations were established this fiscal year at Oakland, California, Salt Lake City, Utah, Sault Ste. Marie, Michigan, and Miami, Florida, where private flying concerns make daily flights under contract for the Weather Bureau. One such station was also established at Fairbanks, Alaska, under an allotment from the Bankhead-Jones Fund for research on a problem concerning the genesis of cold waves in North America. The Canadian Government also established an airplane observation station at Fort Smith, Canada, to provide data for this research project. Excluding the last two stations named, there are now twenty-seven stations of this type operated by the Army, Navy, and Weather Bureau. At each station an aerometeorograph is taken aloft by an airplane each day at about 4:30 a.m., E.S.T. An autographic record of barometric pressure, temperature and relative humidity of the free air, up to an altitude of 16,500 feet above sea level, is obtained from the instrument. The pilot makes visual observations of the height of cloud formations, icing conditions, precipitation, turbulence, etc., encountered during the flight. The data thus obtained are used in the preparation of graphical cross sections of the atmosphere and are of the greatest importance in analyzing day to day weather situations.

Weather Bureau stations have been receiving an increasing number of observations made by airline pilots while in flight. These have been very helpful in completing cross sections and perfecting analyses. Unfortunately, the airline operators do not have standardized procedures in regard to flight observations. Consequently, the reports cannot be fully utilized by meteorological personnel. A graphical method of plotting the flight path, using altitudes as ordinates and geographical distances as abscissa with notes or symbols to indicate height of cloud layers, regions of icing conditions, temperatures, etc., appears to be the most satisfactory method.

Owing to the desirability of obtaining upper air data throughout the troposphere and lower stratosphere, and particularly at times when weather conditions prevent airplane observations, intensive development work on radio meteorographs is being carried on by a number of organizations. The ultimate goal of those engaged in this development, is to perfect a light weight instrument with radio transmitter which, after being attached to a balloon and released, will transmit a record of the barometric pressure, temperature, and relative humidity as it ascends. Such instruments, when developed to the point where they can be relied upon, will largely supplant the present airplane observations. Moreover, with the possibility that radio direction finding can be successfully employed to locate the transmitter attached to the balloon, a method for obtaining upper air winds within and above cloud layers presents itself. The Weather Bureau and the National Bureau of Standards are cooperating in the development of two different types of instruments which are not yet satisfactory for use. Work on the radio direction finding problem will begin early this summer. It is planned to purchase a number of various types of radio-meteorographs for tests with the hope that one can be tentatively adopted for use until further development work is carried out.

A cooperative research project has been undertaken by the Weather Bureau and the Massachusetts Institute of Technology with the object in view of securing aerological data near or within the center of a hurricane. Last summer, three stations were set up in the Gulf States and were supplied with sounding balloons and Jaumotte meteorographs for release if a hurricane passed over or near the stations. Fortunately for the locations but unfortunately for the research project, no hurricanes passed near the stations. This year one or two more stations will be established in this region. If a hurricane approaches one or more of the stations, it is planned to release the meteorographs at intervals of two hours or less during the period of the storm. The instruments, which weigh less than two ounces, will record temperature and relative humidity against pressure on a small smoked glass slide and will be carried to high altitudes by sounding balloons. After the balloons burst, the instruments will return to the ground, later to be picked up by local residents and returned to the bureau or the Massachusetts Institute of Technology for evaluation of the records. In this way, it is expected that the structure of a hurricane will become better understood.

Improvements in the present methods of determining upper-air wind directions and velocities are being investigated. Double-theodolite observations with 16-inch pilot ballons are to be made to determine the free lift required for an ascensional rate 50 per cent greater than that of the 6-inch balloons now in use. It is expected that a balloon of larger diameter with a much faster ascensional rate can be followed to greater heights on days when strong winds prevail and also that the average length of time now required for taking pilot balloon observations can be materially reduced. To facilitate the double-theodolite observations radio-transcievers will be used for communication between the two theodolite stations.

Careful consideration has been given the matter of securing more accurate measurements of ceiling height, particularly at night. This problem was investigated for the Weather Bureau by the National Bureau of Standards and as a result a new design of ceiling-light projector has been adopted, which, it is expected, will permit the measurement of ceiling up to approximately 10,000 feet. This is about three times the height normally measured with the projectors now in use. The new projector is designed to use a 12-volt 35-ampere airplane landing lamp with a 16-inch parabolic mirror mounted behind the lamp and a small auxiliary reflector mounted in front of it. The arrangement permits a highly concentrated intense beam of light to be projected vertically to the cloud layer. Each installation will be made on a base line 750 to 1,000 feet in length, which will permit angular observations of the spot of light on high cloud layers to be made with accuracy.

Space does not permit the summarization of all projects on which the Weather Bureau is engaged. It is pertinent, however, to outline briefly a program for future progress. The short period airway weather forecasts should be improved. A start can be made by having the Meteorologists at the airway forecast centers devote most of their attention to study of hourly sequences, 6-hourly weather maps, cross-sections, upper air charts, pilots' weather observations, and all available information. This will require additional assistance at the forecast centers to carry on the routine and detailed work. All hourly weather reporting teletype stations should be operated by qualified employees who have passed Civil Service examinations. Experience has demonstrated that such stations should not be operated by part-time and relatively inexperienced airway observers. All pilot-balloon stations should take at least four observations a day and the number of such stations should be materially increased in order that more complete upper-air wind information may be available to airline operators and airway weather forecasters. There is great need for the organization of an adequate maintenance and inspection program. This could be accomplished by the assignment of a maintenance inspector and truck to each Weather Bureau airway supervising district. Under such a program all weather reporting stations could be inspected at least once every three months to see that instruments are maintained in good order and that weather observers are taking observations accurately. There is need for an expansion of service in Alaska to aid already established flying operations. Aviation is destined to play an important role in the future development of that region. Observations from ocean areas should be more complete and eventually as many ships as practicable should report weather observations on a six-hourly schedule. It is likely that in the near future the international figure code will be used in the United States and Canada for synoptic reports. This change will permit the inclusion of more detailed meteorological data in coded reports and facilitate the exchange of reports with Canada and foreign countries. Upper-air soundings by radio meteorographs will undoubtedly supplant airplane observations when the instrument becomes further developed. The present cost per instrument will undoubtedly lower as orders for instruments increase and this will permit the establishment of more stations. Such developments as the new open-scale barograph and high powered ceiling-light projector promise to increase the accuracy of airway weather observations. Stations should be equipped with these instruments as rapidly as possible. Finally there is need for the establishment of some additional Weather Bureau airport stations at large municipal airport terminals to provide service similar to that rendered at other large terminals.

The program above outlined is comprehensive, but it is based upon urgent requests from the aviation industry. If it were in effect at the present time, it would go a long way toward solving the weather problems now faced by airline operators.

Mixture Distribution in a Single-Row Radial Engine

HAROLD C. GERRISH and FRED VOSS, *National Advisory Committee for Aeronautics*

(Received December 3, 1936)

THE distribution of the fuel among the various cylinders of aircraft engines is receiving considerable attention because of its effect on fuel economy and torsional vibration. The design of the intake system may cause some of the cylinders to receive leaner mixtures than others. Carburetor adjustments made to enrich the lean cylinders will also enrich the normal mixture in the other cylinders and thus increase the fuel consumption of the engine. The variation of power generated in the cylinders also causes variation in torque and therefore engine vibration, which in some cases may be quite serious.

Exhaust-Gas Analysis

A direct method of determining the distribution among the various cylinders of a multicylinder engine is to measure the fuel and air entering each cylinder. The inconvenience of such procedure necessitates the adoption of indirect methods, such as noting the variation in engine power when the spark plugs of each cylinder in turn are short circuited, analyzing indicator cards or the exhaust gas taken from the individual cylinders, and by noting the difference in temperature of the cylinder heads. The method of exhaust-gas analysis was used in the work covered by this paper.

The investigation was made to determine the variation in the quality of the mixture among the cylinders of a multicylinder aircraft engine and the factors that affect the mixture distribution.

A Pratt & Whitney 1340 SIHl-G aircraft engine with a controllable propeller was used. The induction system on this engine consists of an air-scoop, carburetor, and a blower operating at 12 times engine speed. From the blower, 9 tubes of equal length and diameter carry the carbureted mixture to the cylinders. The exhaust gas from one cylinder is used to heat the carburetor. The engine and nacelle were mounted in the N.A.C.A. 20-foot wind tunnel.

The engine power was varied from 340 to 487 i.hp., the fuel consumption from 0.42 to 0.59 lb./i.hp.-hr., and two engine speeds were used: 1,665 and 1,800 r.p.m. Army Specification No. Y-3557-G gasoline having an octane rating of 87 was used as fuel for all tests.

The exhaust-gas samples were extracted through nine 40-foot lengths of ¼-inch outside-diameter tubing, one length for each exhaust stack. One end of each tube was located in the center of the exhaust stack approximately 1 inch from the exhaust valve. Steel was used for this portion, approximately 6 feet, because of the high exhaust-gas temperature. Aluminum tubing was used for the remaining 34 feet because of the ease with which it could be led through the engine nacelle and engine support to the test chamber of the wind tunnel.

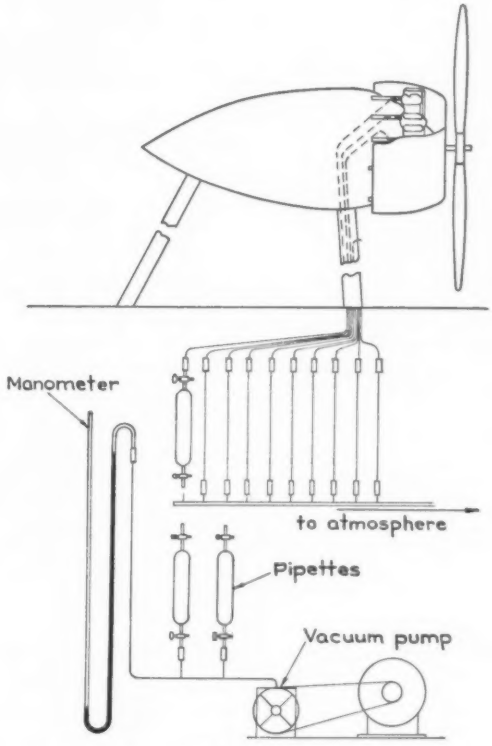

FIG. 1. Set-up of apparatus.

The tubes were mounted in the test chamber so that the exhaust gases from each cylinder flowed through spacer tubes into a manifold and then to the outside of the test chamber through suitable piping. The spacer sections of tubing permitted the insertion of the sampling pipettes. A diagrammatic sketch of the set-up is shown in Fig. 1.

The exhaust-gas samples were collected in evacuated glass-sampling pipettes, each having a volume of approximately 250 cubic centimeters. Twenty-four of the samples were completely analyzed to establish the relation of CO_2, CO, and equivalent fuel wasted to the air-fuel ratio. The equivalent fuel wasted is the fuel equiv-

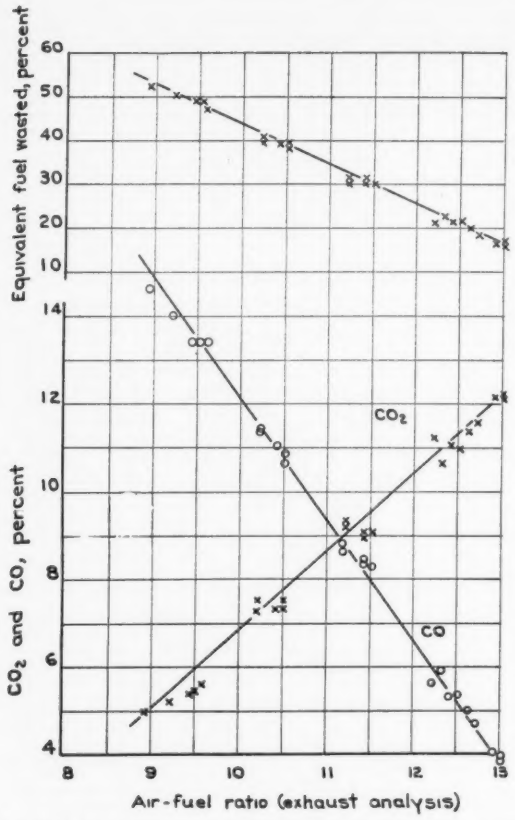

FIG. 2. Relation of CO, CO_2 and equivalent fuel wasted to air-fuel ratio.

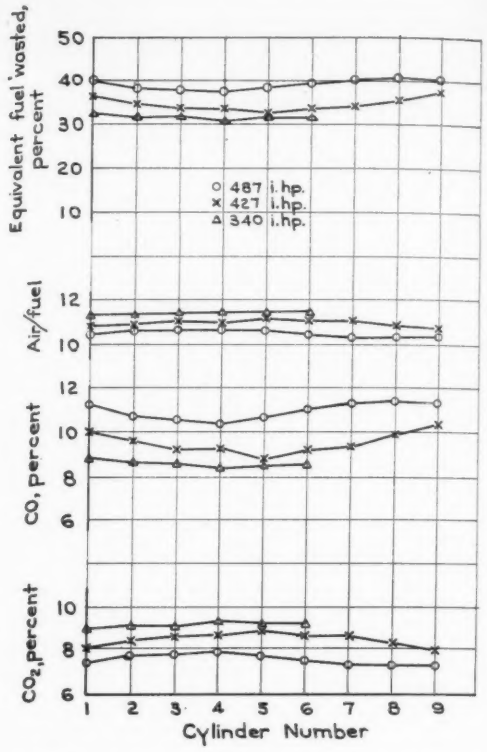

FIG. 3. Effect of engine power on distribution (1,800 r.p.m.; 0.55 to 0.58 lb./i.hp.-hr.).

alent of the unburned combustibles in the exhaust gases and was calculated from the heating values of combustibles given in the International Critical Tables. Fig. 2 shows the relations found. All other samples were analyzed only for CO_2. The CO content, the air-fuel ratio, and the equivalent fuel wasted for these samples were then obtained from this figure.

The temperature of the rear spark-plug bosses was determined by thermocouples and recording pyrometers. Holes were drilled in the spark-plug bosses and the thermocouples peened in place. Engine power was determined from the b.hp. and f.hp. curves furnished by the engine manufacturer. The fuel consumption was determined by the use of N.A.C.A. fuel flowmeters.

RESULTS

The distribution characteristics of this engine at various power outputs, specific fuel consumptions, and engine speeds are shown in Figs. 3 and 4. The curves cover the mixture range within which this engine normally operates. Each curve shows the same trend and indicates that the top cylinders operated with a lower air-fuel ratio than the bottom ones. The leaning of the bottom cylinders irrespective of power output, specific fuel consumption, and engine speed was an interesting result. An examination of the curves shows that the quality of the mixture as measured by the air-fuel ratio generally varies about 4 percent for each condition. These figures also show that as the air-fuel ratio is increased, the CO_2 content increases and the CO content and the fuel wasted decrease.

Fig. 3 shows the results obtained with constant engine speed and constant specific fuel consumption but variable horsepower. As would be expected, the curves show that the air-fuel ratio had to be decreased with increase in the power output for the power range investigated to maintain the desired fuel consumption. The effect of maintaining a constant specific fuel consumption with increase of power output on the hazard of CO poisoning is shown by the large increase in the CO content. Although the specific fuel consumption was maintained constant, the combustibles in the exhaust increased approximately 25 percent as shown by the curves of equivalent fuel wasted.

Fig. 4 shows the results obtained from four conditions of constant power output and engine speed but variable specific fuel consumption. Increasing the specific fuel consumption decreased the CO_2 content and the air-fuel ratio but increased the CO and the percentage of fuel wasted.

Fig. 5 shows the temperature of the rear spark-

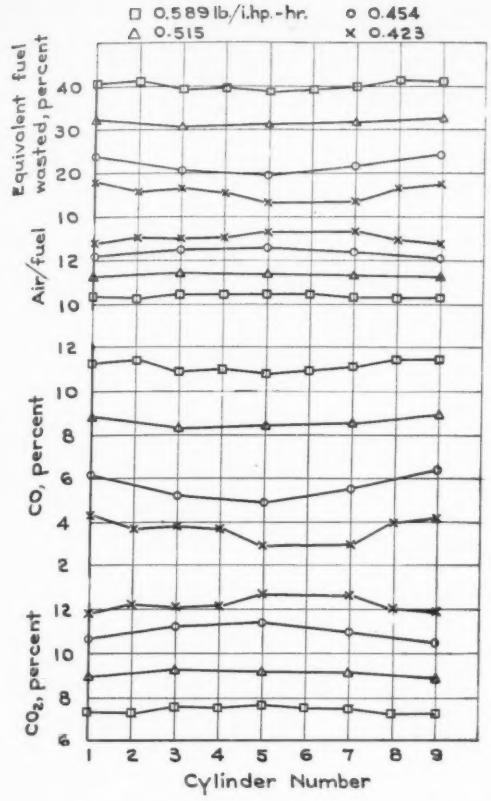

FIG. 4. Effect of specific fuel consumption on distribution (1,665 r.p.m.; 457 i.hp.).

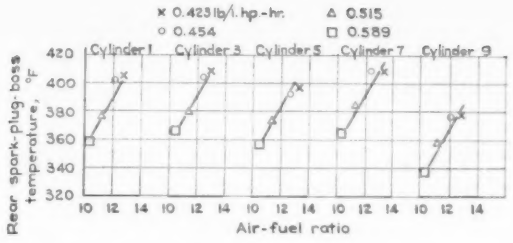

FIG. 5. Effect of air-fuel ratio on temperatures of rear spark-plug boss (1,665 r.p.m.; 457 i.hp.).

plug boss taken during the four variable-fuel-consumption runs shown in Fig. 4. These curves indicate that the temperature of each cylinder increases with the leaning of the mixture in that cylinder. The relation of temperature and mixture strength, however, varies from cylinder to cylinder. Cylinder 5 shows the leanest mixture but not the maximum temperature recorded during these runs. Cylinder 9, which has very nearly the same air-fuel ratio for the different specific fuel consumptions as the adjacent cylinder 1, has considerably lower temperature. On the other hand, the relation between temperature and mixture strength is practically the same for cylinders 1, 3, and 7. It is concluded that for the range of air-fuel ratios covered in this investigation, the temperature of the rear spark-plug boss is not a good indicator of the mixture strength in the cylinder.

Time Loss in Cross-Wind Flight

A. F. ZAHM, *Library of Congress*

(Received November 3, 1936)

Summary

DRIFT loss is calculated for cross-wind flight of a craft (1) when sidling along a straight course toward its goal, and (2) when "homing" over a curved path, headed constantly goalward. The homing time varies as the square of the sidling time. For usual transport conditions the loss in homing is twice that in sidling flight. Both losses are small and both increase nearly as the square of the cross-wind speed.

Preface

When an aircraft pursues a plane level course from A to O in a wind blowing squarely across AO it may either sidle straight along AO or head constantly toward O and follow a curved path, as shown in Fig. 1. The times of passage in such "sidling" and "homing" flight, ignoring the earth's sphericity, are to be compared with the time T_0 of direct flight with no wind. This standard time may be written

$$T_0 = a/v \tag{1}$$

where $a = AO$ and v is the constant cruising speed.

Sidling Flight

In rectilinear sidling flight square across a uniform wind of speed w, the craft must point off course so much that its cruising velocity v has the component $-w$ along wind and $(v^2-w^2)^{\frac{1}{2}} \equiv u$., along the straight path. Then the passage time is $T_1 = a/u$, or

$$T_1/T_0 = v/u = \sec \beta \tag{2}$$

where β is the sidling angle, or inclination of v to the flight path. Thus T_1 ranges from a/v to ∞ as w grows from o to v; it becomes imaginary for $w>v$. For β small $(T_1-T_0) \propto \beta^2$ nearly, or the increment of passage time varies nearly as the square of the sidling angle; that is for w/v small the time loss varies nearly as w^2 for constant cruising speed v.

Homing Flight

When in such cross wind the craft heads constantly toward O, let its path coordinates be r, ϕ, as in Fig. 1. Then clearly

$$\dot{r} = w \sin \phi - v \qquad r\dot{\phi} = w \cos \phi \tag{3}$$

where $\dot{r}$ and $r\phi$ are the resultant velocity components along and normal to r. Eliminating t gives the path equation

$$\frac{dr}{r} = (\tan \phi - n \sec \phi)\, d\phi$$

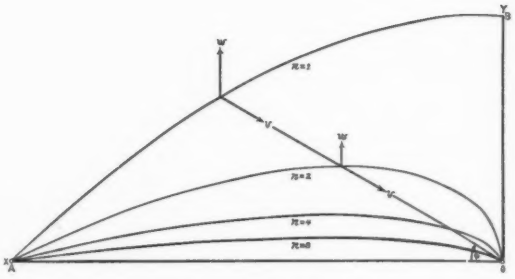

Fig. 1. Flight paths in cross winds of various speeds w, at fixed cruising speed v, of aircraft heading toward 0; $n = v/w$.

where $n = v/w$. The integral reduces to

$$r = a \sec \phi\, (\sec \phi - \tan \phi)^n \tag{4}$$

Sample paths are plotted in Fig. 1. For $n=1$ the line (4) ends at B distant $a/2$ from O; for $n>1$ all paths lie within AB; for $n<1$ all paths lie beyond AB; the inner ones touch Y at $y = 0$, the outer at $y = \infty$. The dividing line can be deemed to split at B, one branch running plumb down to O the other plumb up to ∞.

The features of (4) need not be treated at length. The slope is $-w/v$ at $\phi = 0$ and ∞ at $\phi = \pi/2$. The widest departure, $y_{max.}$, occurs where $\sin \phi = w/v$, and usually is small, as seen in Table I. The graphs show that ordinary cross winds do not greatly lengthen the path of a fast plane in homing flight.

The time of passage T_2 may be found from

$$x = a\, (\sec \phi - \tan \phi)^n \qquad v \cos \phi = -dx/dt$$

on eliminating x and integrating. It is

$$T_2/T_0 = \frac{v}{a}\int_0^{T_2} dt = n \int_0^{\pi/2} (\sec \phi - \tan \phi)^n \sec^2 \phi\, d\phi$$

$$= \frac{n^2}{n^2-1} \tag{5}$$

Thus if $n=1, 2, 3, 4$ etc., the integral is ∞, 4/3, 9/8, 16/15, etc., each of which equals $n^2/(n^2-1)$.

Comparison of Homing and Sidling Times

Now since $v^2 - w^2 = u^2$, and $n = v/u$, Eq. (5) may be written

$$T_2/T_0 = v^2/u^2 = T_1^2/T_0^2 \tag{6}$$

which is the relation sought. It shows that $T_2 \propto T_1^2$.

The passage times Eqs. (2) and (6), are expressed by two simple laws: (a) the sidling time varies as the secant of the sidling angle; (b) the homing time varies as the square of the sidling time. Table 1 gives both in terms of T_0, the still air time of passage.

TABLE 1

Passage time and side drift for aircraft of cruising speed v in cross winds of speed w

$n = v/w$	1	2	3	4	5	6	7	8	9	10
Homing time $T_2/T_0 = \frac{n^2}{n^2-1}$	∞	1.3333	1.1250	1.0667	1.0417	1.0284	1.0208	1.0159	1.0125	1.0101
Sidling time $T_1/T_0 = \sqrt{T_2/T_0}$	∞	1.1547	1.0605	1.0327	1.02085	1.0142	1.0104	1.00795	1.00625	1.00505
Side drift $y_{max.}/a$	0.500	0.1924		0.0929		0.0553		0.0463		0.0369

For any small time loss ϵ in sidling flight a loss 2ϵ in homing flight appears. Obviously so, since $(1+\epsilon)^2=1+2\epsilon$ if ϵ is small enough. Both are small in common transport flying. Thus, a plane cruising at 180 m.p.h. across a 25 m.p.h. wind suffers a time loss of 1% in sidling, 2% in homing flight. For v/w large the time loss ϵ increases roughly as the square of the wind speed w if the cruising speed v is constant. This approximate relation, $\epsilon \propto w^2$, can be read from Table 1 or deduced from Eq. (3), as shown there.

MORE GENERAL FLIGHT CONDITIONS

In case the wind of constant speed w blows uniformly across AO at a constant angle i, the resultant velocity components along and across r can be written

$$\dot{r} = w \sin \alpha - v \qquad r\dot{\phi} = w \cos \alpha$$

where $\alpha = (\pi/2) - (i - \phi)$. Comparison with Eqs. (3) and (4), therefore gives

$$\dot{r} = a \sec \alpha \, (\sec \alpha - \tan \alpha)^n \qquad (7)$$

This may be analysed as for homing flight in a square cross wind having $i = \pi/2$, or $\alpha = \phi$. For a head wind along AO clearly $i=o$, for a tail wind $i=\pi$; the first gives $\alpha = \phi + \pi/2$, the second $\alpha = \phi - \pi/2$. Hence for the assumed oblique cross wind the path (7) is of simple form for analysis.

Much more general flight conditions oftentimes prevail and might tempt further academic computation. Only the simpler cases have been treated here as possibly offering some hints for practical navigation. For example, the formulas may be used to direct the pilot how much off course to point his craft in order to sidle onward to port in the shortest time when unguided by ground line or radiant beam, or how much to raise his cruising speed to maintain schedule despite the small drift loss.

Modification to the Longitudinal Stability Derivatives With the Constant-Speed Propeller

ARTHUR G. B. METCALF, *Boston University*

(Received January 7, 1937)

IN a recent paper[1] certain expressions were employed in the evaluation of the longitudinal stability derivatives for flight with power. These expressions, in part, were based upon propeller considerations involving an approximate expression, due to Glauert, for the variation of thrust with forward speed for the fixed pitch propeller.

The increasing use of the constant-speed propeller makes it necessary to determine the modifications to the derivatives for airplanes equipped with this device.

With constant engine brake-horsepower,

$$\frac{(\text{t.hp.})}{(\text{t.hp.})_1} = \frac{\eta}{\eta_1} \quad ,$$

where (t.hp.)=thrust horsepower available, η = propulsive efficiency, and the subscript, 1, refers to conditions at the speed of maximum propulsive efficiency.

The efficiency for constant r.p.m. has been computed from the well-known N.A.C.A. propeller charts for varying velocity and the average relation between the efficiency ratio and the velocity ratio is plotted for the "best performance" and "peak efficiency" propellers in T.N. 579.[2] This plot leads to the evaluation of an approximate expression for the ratio of thrust to thrust at maximum efficiency, as a function of the velocity ratio, having the form:

$$\frac{T}{T_1} = \frac{\eta}{\eta_1}\frac{U_1}{U} \quad ,$$

where T = thrust, T_1 = thrust at η_1,

U_1 = design speed at altitude under consideration at $\eta_{max.}$, with a given b.hp.

U = equilibrium speed for which stability is being investigated.

An expression of the form used by Glauert with respect to the fixed pitch propeller, fitted to the propeller data, results in a very satisfactory description of the relation for the "best performance" propeller, *viz.*:

$$\frac{T}{T_1} = 2.04 - 1.04\,\frac{U}{U_1} \qquad (1)$$

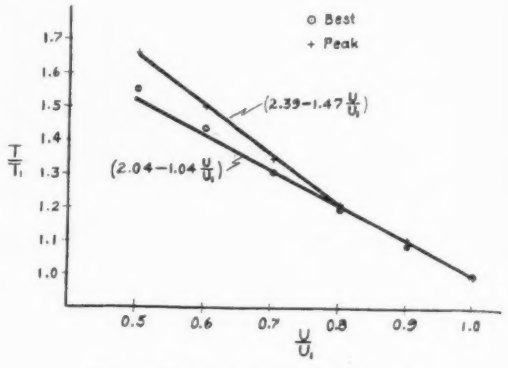

FIG. 1. Thrust ratio *vs.* velocity ratio.

This applies to values of U/U_1 from 1.00 to at least as low as 0.5.

For the "peak efficiency" propeller this expression is less satisfactory for the lower values of U/U_1 between 0.8 and 0.5 where in this range it would be better to write:

$$\frac{T}{T_1} = 2.39 - 1.47\,\frac{U}{U_1} \qquad (2)$$

Fig. 1 presents plots of these expressions. Points calculated from the propeller data are indicated and it is seen that for either propeller, the mean variation may be represented, with sufficient precision, by the suggested linear relations. It is to be noted that for the "peak" propeller for values of U/U_1 greater than 0.8, the variation is substantially identical with that for the "best" propeller and Eq. (1) may be used as a basis for calculating derivatives for either propeller.

Assuming the thrust line is not far from the C. G., and that for m_w, the effect of slipstream is approximately balanced by the change in $d\varepsilon/d\alpha$ with power, the derivatives which are materially affected by power-on conditions are:

$$x_u = 2C_D + K_1\left(\frac{C_{D_1}}{C_{L_1}}\right)\sqrt{C_{L_1}C_L} \quad ,$$

$$m_q = \frac{1}{\eta}\,\frac{5}{4}\,e\left(\frac{dC_L}{d\alpha}\right)'\frac{S'}{S}\left[1 + Q(R-1)\right] \quad ,$$

and

$$m_u = \frac{C_{m_{WBG}}}{\eta}\,\frac{C}{L}\,\frac{Q}{1+Q(R-1)}\left(U\frac{dR}{dU}\right).$$

[1] A. G. B. Metcalf, *Airplane Longitudinal Stability, A Résumé*, Journal Aeronautical Sciences, Vol. 4, No. 2, 1936.

[2] R. J. White and V. J. Martin, *Charts for Calculating the Performance of Airplanes Having Constant-Speed Propellers.* N. A. C. A., Tech. Note 579, 1936.

TABLE 1

Constant-speed propeller	K_1	K_2
Best performance prop. $\frac{U}{U_1}$ from 1.0 to 0.5	1.04	2.04
Peak efficiency prop. $\frac{U}{U_1}$ from 1.0 to 0.8	1.04	2.04
Peak efficiency prop. $\frac{U}{U_1}$ from 0.8 to 0.5	1.47	2.39
Fixed-pitch propeller. Approx. for Peak or best propeller $\frac{U}{U_1}$ from 1.0 to 0.5	0.62	1.62*

* Note: In the earlier paper (see footnote 1 of this paper) an error in printing caused $2K_2$ to appear as .324 in the expressions for the power-on derivatives. The correct value is 3.24.

Where

$$(R-1) = -\frac{4S}{N\pi D^2} C_L \left(\frac{C_{D_1}}{C_{L_1}}\right)\left(K_2 - K_1\sqrt{\frac{C_{L_1}}{C_L}}\right),$$

$$U\frac{dR}{dU} = -\frac{4S}{N\pi D^2} C_L \left(\frac{C_{D_1}}{C_{L_1}}\right)\left(K_1\sqrt{\frac{C_{L_1}}{C_L}} - 2K_2\right)$$

and the path angle, θ, with power, is

$$\theta = \frac{C_{D1}}{C_{L1}}\left(K_2 - K_1\sqrt{\frac{C_L}{C_L}}\right) - \frac{C_D}{C_L}$$

The symbols used here have been defined in the earlier paper[3] by the writer.

The appropriate values of K_1 and K_2 with the constant-speed propeller, for use in these expressions are given in Table 1. These are based on Eqs. (1) and (2) and are well within the limit of accuracy with which the derivatives may be calculated.

[3] *Airplane Longitudinal Stability, A Résumé,* loc cit. supra.

Book Reviews

Aerial Odyssey, by E. ALEXANDER POWELL; The Macmillan Co., New York, 1936; 292 pages, $2.50.

When an author of more than a score of books directs his talents to writing what is really a guide book to the ports of the Caribbean and Gulf of Mexico, which are reached by Pan American Airways, an interesting book was sure to be the result. It will be indispensable to those who wish to find in one volume a descriptive account of an air traveller to Central America. Mr. Powell tells just what the traveler wants to know of the historical background of each place and describes his own adventures both in the cities and off the beaten track. It is an airplane view of a most romantic region.

Your Wings, by ASSEN JORDANOFF, Funk & Wagnalls Company, New York, 1937; 281 pages, ill., $2.50.

This book of twenty-seven chapters and over 425 pen and ink illustrations, admirably fills a need in that the author has reduced the technical terminology and phrases of all phases of aeronautics to simple, easily understood terms. The author first makes clear the basic principles of flight, and then, with the aid of his many illustrations, carries the reader through a complete course in flying, from the first flight to most advanced maneuvers.

The book is recommended particularly for youngsters of high-school age and for the layman.

Aircraft and the Air, by ERIC SARGENT; D. Appleton-Century Company, New York; 1936, 682 pages, ill., $3.00.

This handbook of nearly seven hundred pages is a welcome addition to the comparatively few reference books on types of airplanes, and airships. There are about three hundred drawings of leading aircraft of all countries. The accompanying descriptive information is standardized so that the facts regarding the characteristics of any type are easily found. In addition to the aircraft section there are chapters on the history of aviation, gliding, parachutes, instruments, airdromes and air transport. While the sketches in the book are not artistically drawn they have certain advantages over photographs in showing details. One of the disadvantages of books of this type is that they become out of date in about a year. It therefore is natural to hope that annual revisions will be made by Mr. Sargent so that it will continue in the future to be helpful to the aeronautical profession.

Acrobatic and Inverted Flying Manual, by LIEUT. JOSEPH C. MACKEY; The Aircraft Directory, Ohio, 1936; 43 pages, ill., $1.00.

This short pamphlet of forty-three pages gives pilots information regarding stunt flying in concise form and in a style that can be easily understood by students who wish to attempt acrobatics. Not the least important value of the work are the warnings regarding the dangers encountered.

Institute Notes

Honors

D. R. Pye, an Associate Fellow of the Institute, has been appointed Director of Scientific Research of the Air Ministry of England to succeed H. E. Wimperis, who is retiring.

W. S. Farren, also an Associate Fellow of the Institute, is to be Deputy Director.

Mr. Pye was born in 1886 and was educated at Tonbridge School and at Trinity College, Cambridge. He served as a pilot and experimental officer in the Royal Flying Corps and Royal Air Force during the War 1914–18, and has been Deputy Director of Scientific Research at the Air Ministry since 1925.

Mr. Farren is a Fellow of Trinity College, Cambridge, and a Lecturer in Aeronautical subjects at the University. He was employed on experimental work at the Royal Aircraft Establishment during the War 1914–18, and has also been with Armstrong Whitworth Aircraft Ltd. In recent years he has been a member of the Aeronautical Research Committee, and has also served on many of its sub-committees.

Meeting of the Pacific Coast Section

At a meeting of the Pacific Coast section on Friday, February 19, 1937, the following were elected to serve on the Executive Committee for the coming year: C. L. Egtvedt (Boeing), H. L. Hibbard (Lockheed), Th. von Karman (California Tech.), J. K. Northrop (Northrop), A. E. Raymond (Douglas), E. G. Reid (Stanford University), G. F. Vultee (Vultee), B. M. Woods (University of California), J. L. Atwood (North American), I. M. Laddon (Consolidated) and C. E. Stryker (Curtiss Wright Technical Institute).

The meeting was held at the Deauville Club in Santa Monica, about 150 attending the dinner and about 225 attending the technical session which followed.

E. E. Sechler of the California Institute of Technology gave a brief summary of papers given at the Annual Meeting of the Institute in January on Structural subjects. Clark B. Millikan gave a very complete and interesting talk summarizing and commenting on papers given at the meeting on the subjects of aerodynamics, meteorology and instruments. The possibility of getting weather data by use of the Radio-Meteorograph during overcast weather conditions was commented on and the hope expressed that this instrument would solve the problem now existent of obtaining weather information when it is most needed. This subject and the comments appeared very timely in view of the other speaker on the program.

D. W. Tomlinson of T.W.A. gave an exceptionally interesting talk on various test flights made by him at high altitudes. Mr. Tomlinson's experiences at altitudes of 30,000 to 35,000 feet were not only interesting to hear about from the narrative viewpoint, but the very definite and careful observations made will serve to clarify the designer's information of conditions existent. He measured ground speeds of 370 to 384 m.p.h. with the Northrop Gamma, indicating wind velocities of 150 m.p.h. In several cases he descended through solid clouds 20,000 to 22,000 feet thick extending up to an altitude of 30,000 feet. These flights to high altitudes serve a very important need to check actual conditions and problems occurring there.

The meeting concluded with motion pictures of films loaned to the Section by the Institute, showing the new laboratories and wind tunnels of England, Germany and Italy. The running commentary accompanying the films was read by Clark B. Millikan.

Student Branches

University of Detroit. A meeting of this Student Branch was held on January 28, 1937, in the Engineering Building of the University. Charles Norton, Detroit representative of Dupont Nemours, Inc., spoke on "Neoprene or Synthetic Rubber." He discussed this recent development of Dupont's and compared its physical properties with that of ordinary rubber. He also showed samples which illustrated the uses of Neoprene. Mr. Dallas, Chief Stress Analyst of the Stinson Aircraft Corporation, was the second speaker, and talked on "Design, Production, and Testing of Private Owner Airplanes." In his discussion he stressed the problems and reasons in using various types of construction and design. An open forum was conducted at the close of the talk. An inspection trip to the Stinson Aircraft Corporation was conducted by this Student Branch on Saturday, February 20, 1937. The group was permitted to go through the factory while it was in operation, and allowed to see the construction of the 1937 Stinson Reliant from start to finish. The service hangar and the flying field where the new ships are tested before delivery were also visited.

University of Michigan. A meeting of this Student Branch was held on Monday, January 11, 1937, in the Engineering Building of the University. The speaker of the evening was Francis L. Wallace, a graduate of the course in Aeronautical Engineering, who is at present with United Air Lines as co-pilot. The first part of his talk was devoted to a discussion of his duties and experiences flying as co-pilot. At the conclusion of his talk he answered questions concerning airline operation.

University of Michigan. A meeting of this Student Branch of the Institute was held on Thursday, February 18, 1937. About forty-five members were present. M. J. Thompson, B. L. Springer and W. C. Nelson, who had attended the Annual Meeting of the Institute, reviewed a number of the papers that had been presented at the meeting. Recent developments in aeronautics were discussed with considerable interest by the speakers. Mention was made of the newly created Lawrence Sperry Award, presented annually to some young man for outstanding work in aeronautics. A discussion was held regarding the possibility of sending student delegates to the next annual meeting.

University of Minnesota. Two meetings were held by this Student Branch during the month of January. At the first, held on the evening of January 14, sound motion pictures were shown. The pictures were of various short subjects, among them were "Oscillographic Measurement of Sound," "Automobile Transmission Gearing," "Motor Car Testing" and pictures of a gas-driven model airplane contest. A business meeting was held on January 28 in the main engineering building.

Necrology

Prof. Dr. Erich Trefftz, an Associate Fellow of the Institute, died on January 21, 1937, at Dresden, Germany. Professor Trefftz was born in Leipzig February 21, 1888. He studied at Aachen, Goettinger and Strassburg Universities. He served as an officer during the War.

In 1918 he became professor of mathematics at the Aachen Polytechnic Academy and in 1922 became professor of mechanical engineering at the Dresden Polytechnic Academy. He joined the staff of the D. V. L. in 1936.

Harris M. Hanshue, an Industrial Member of the Institute, died January 8, 1937, in New York City. Mr. Hanshue was one of the organizers of the airline which became the Western Air Express. He had also been President of the Fokker Aircraft Corporation, a director of the National Aviation Corporation and the Pacific Zeppelin Transport Company. His most recent interest was the Waterman Airplane Company of Santa Monica, California.

Mr. Hanshue was engaged in the automobile business before becoming interested in aviation. He was 55 years old at the time of his death.

Charles Hayden, an industrial Member of the Institute, died January 8, 1937, at his apartment at the Hotel Savoy Plaza, New York City. He was 66 years old and had been seriously ill for several weeks.

He was born in Boston on July 9, 1870. After a public school education, he attended the Massachusetts Institute of Technology, receiving a degree of B.Sc. in 1890. In 1892 he founded the banking firm of Hayden, Stone & Company, of New York City and Boston, and was a senior partner at the time of his death.

Mr. Hayden was one of the organizers of the Wright Aeronautical Corporation and later assisted in the consolidation of the Wright and Curtis groups. He retained an active interest in the Curtiss-Wright Corporation until his death.

His gifts to public causes were many. He gave generously to M.I.T. during his lifetime and bequeathed it $1,000,000 by his will. He gave $150,000 toward the erection of the planetarium which bears his name at the American Museum of Natural History in New York.

At the time of his death he was on the board of many corporations. By his will be left his fortune to establish a foundation to benefit young men.

Personnel Opportunities

The Personnel Bureau serves organizations seeking to employ aeronautical specialists as well as individual members. The Bureau has been the means of arranging several very successful connections for members.

Any member or organization may have requirements listed without charge.

Wanted

Experienced engineers and draftsmen desired by middle-west aircraft company. Write Box 53, Institute of the Aeronautical Sciences.

Available

Engineer Executive available for consultation or permanent position. Long experience in charge of engine design, development and construction for the U. S. and foreign governments and private companies. Write Box 54, Institute of the Aeronautical Sciences.

Engineer wishes to make research connection. Seven years experience on wind structure and atmospheric turbulence research, including special electrical instrument design and statistical analysis of data obtained. Doctor of Science in Electrical Engineering, University of Michigan. Specialization, mathematics and circuit analysis. Write Box 55, Institute of the Aeronautical Sciences.

Graduate Aeronautical Engineer desires a teaching position in public or private school in the East. Master of Science in Physics and Aeronautical Engineering degree. Has teaching certificate for New Jersey High Schools, and has two years teaching experience in that state as aviation instructor. Write Box 56, Institute of the Aeronautical Sciences.

Book Reviews

Aviation in the Public Schools, by ROBERT W. HAMBROOK; Vocational Education Bulletin No. 185, Trade and Industrial Series No. 53; United States Government Printing Office, Washington, D. C., 1936; 78 pages, ill., 15 cents.

This pamphlet will be of service to those engaged in aeronautics who are asked by friends to assist in securing employment in aviation for some young man. In such cases much time is required to explain the extent of the various occupations which are used in air transport, aircraft construction or allied industries. The purpose of the Office of Education in preparing this booklet is primarily to acquaint schools with the value of aeronautical instruction and to show what opportunities are offered for aviation employment.

In addition to giving outlines for courses in primary aeronautical science, general aeronautical information, meteorology, air navigation and model construction, it gives, in detail, the breadth of aviation occupations. By studying these, young men or young women can decide what specialty they wish to follow and prepare themselves for the work so that when they are asked as to their qualifications they will not reply "I want a job and think that aviation is as good as anything else," which the pamphlet gives as one of the stock replies given by applicants for positions.

A Plan for the Organisation of a European Air Service, by REAR ADMIRAL R. N. LAWSON, C.B.; Constable & Co. Ltd., London, 1936; 44 pages, 2/6.

Some discussions on air power are intended to be provocative but when they become irritating precaution must be taken not to reflect the same spirit in criticizing the point of view of an author. Apparently this retired naval officer has occupied his leisure moments outlining an idealistic conception of an international police force based on European air transport. Not content with combining the air lines of Europe, he calmly establishes a demilitarized neutral zone ten miles wide between all European countries and suggests that Russia should agree not to send her military aircraft west of her borders in return for their defense by his imaginary European Air Police. He will not admit that nations have the right to control the air over their territory. He gives this domain to his police force. Naturally, his views on naval aircraft come close to his experiences and may be considered more seriously. His statement "Loyalty to navy transcends loyalty to nation; not in words but in reality" is the precept he expects his theoretical airmen to follow. He does not believe that naval aircraft should be pooled until nations outside Europe agree to abolish their naval air forces.

Enough has been given to indicate the pacificist point of view of this work. The study was prepared before the collapse of the League of Nations sanctions and apparently did not consider the similar plan proposed by Clifford B. Harmon several years ago. It is truly a masterpiece of impractical ideas.

LESTER D. GARDNER

High Failure, by JOHN GRIERSON; William Hodge & Company, Limited; London, 1936; 305 pages, ill., 12s.6d.

There have been so many different kinds of transatlantic flights that it has been difficult to evaluate the purposes that prompted pilots to take the risks involved. No doubt is left in the mind of the reader as to the purpose of the author. He was not pioneering a new route. He was not using equipment that an air line would use. He was not trying to better a record. He was just another young pilot who wanted to show that he could cross by the most northerly practicable route in a small single-engined Fox Moth. That he finally reached New York from London is creditable to his determination and skill as a private pilot. The book is an interesting diary of an air journey via Iceland, over the ice cap of Greenland and along the shores of Hudson Bay, and is good reading. Some day when ice and other weather deterrents are conquered and the route across the Atlantic requiring the shortest possible hops across the ocean becomes available, Grierson may properly be regarded as a pathfinder. But it is more probable that by that time airplanes will be crossing non-stop direct and the early pilots who took great chances will be respected for their courage more than for their contributions to the advancement of transoceanic flying.

Transport Examiner, by LIEUT. E. G. VETTER; Rochester, N. Y., 1936; 61 pages (mimeographed).

This pamphlet is not susceptible of a review but as an aid to applicants for Transport licenses it will prove to be a useful refresher. In question and answer form it reviews Air Commerce Regulations, Air Traffic Rules, Engines, Airplanes, Meteorology and Navigation, giving concisely the replies he should be familiar with to pass his tests.

The Modern Book of Aeroplanes, by W. H. MCCORMICK; The Macmillan Company, New York; 142 pages, ill., $2.40.

For a clear and simple story of aviation from its beginnings, this addition to the already large number of general books on aircraft and flying will be found interesting by those who wish to scan quickly the progress made in the conquest of the air. The gravure illustrations are not only carefully chosen but are beautifully reproduced.

It is only natural that the book should emphasize somewhat unduly the development of British aeronautics. As instances the chapter on "Airways of the World" is devoted exclusively to the Imperial Airways, and in the chapter on races only the Schneider Trophy, King's Cup and MacRobertson races are mentioned.

The historical sections of the book are well written and give a clear summary of both lighter-than-air and heavier-than-air development. The author makes an error in his description of the Langley flights of having the subsequent trials take place on the "River Potomac" instead of on Lake Keuka, with no mention of the structural changes made in the machine. His positive assertion that if the original machine had flown as well "Langley would then have been honoured as the inventor of the first man carrying machine capable of flight" is the precise inaccurate statement that caused the original Wright Brothers' airplane to be placed in the South Kensington Museum.

Model Aircraft Book, 144 pages, ill., 3s.6d.; **Power Driven Aircraft,** 96 pages, ill., 1s.; **Model Aeroplanes and Airships,** 96 pages, ill., 1s.: by F. J. CAMM; George Newnes. Limited, London.

These three books supplement each other. The former is an advanced course in model aircraft construction while the other two may be regarded as guides to beginners. The growth of model flying clubs has been one of the extraordinary phenomena of aviation. Hundreds of thousands of youngsters in all parts of the world are making models of every type of aircraft. The advent of miniature engines suitable for installation in models has broadened the field by permitting the construction of larger types than could be propelled by the conventional rubber cord. The enthusiasm of these young model builders is not excelled in any other hobby field and the information they secure is amazing, especially when aircraft engineers are subjected to cross questioning. It is from such books as those of Mr. Camm that many airmen of the future learn the rudiments of aviation.

Sky Gypsy, by CLAUDIA CRANSTON; J. B. Lippincott Company, Philadelphia, Pa., 325 pages, ill., $2.50.

Of books on air travel there apparently is no end, which is fortunate for air transport as each new descriptive volume creates an urge in the minds of many readers to visit countries which have hitherto been comparatively inaccessible. This is particularly true of the Pan American Airways routes. Instead of months being required to see the romantic and historical coastal cities of Central and South America, a few weeks now suffice for an air tour which almost invariably results in a series of articles or a book when the air tourist is a trained writer. Miss Cranston is one of those fortunate travellers who enjoys recording her observations and making them readable. She has in her travelogue of 25,000 miles of flying in Clipper Ships emphasized the picturesque side of the trip, and has interwoven the historical background so that it does not become "guide bookish." While the book is essentially feminine in its viewpoint, it adds another type of description to the field of voyager's experiences.

Exchanges

The Institute exchanges the Journal with many other aeronautical periodicals. They are kept on file at the Skyport in Rockefeller Center, New York City, where members may read them. As readers of the Journal may wish to subscribe to some of them, a list of these periodicals with their addresses is published here. Information regarding subscription prices may be secured from the Secretary of the Institute.

Aero, Maneesikatu 2, Helsingfors, Finland.

Aero Digest, 515 Madison Ave., New York City.

Aeronautica Argentina, Velez Sarsfield 57, Cordoba, Argentina

L'Aeronautique, 55 Quai des Grands-Augustins, Paris, France.

L'Aerophile, 7 Rue Saint-Lazare, Paris, France.

The Aeroplane, 175 Piccadilly, London, W.1, England.

L'Aerotecnica, Via delle Coppelle 35, Rome, Italy.

Les Ailes, 77 Boulevard Malesherbes, Paris, France.

Aircraft Engineering, 2 Bloomsbury Place, London, E.C.1, England.

Air Law Review, Washington Square East, New York City.

Asas, Caixa Postal 1967, Rio de Janeiro, Brazil.

Astronautics, American Rocket Society, 31 West 86th Street, New York, N. Y.

Aviation, 330 West 42nd St., New York City.

L'Aviazione, Corso Umberto 504, Rome, Italy.

Boletin de Aeronautica Civil, Calle Azcuenaga 923, Buenos Aires, Argentina.

Boletin Oficial de la Direccion General de Aeronautica, Magdalena 12, Madrid, Spain.

Bulletin du Service Technique de l'Aeronautique, 72 chaussee de Waterloo, Rhode-Saint-Genese, Belgium.

Bulletin of the American Meteorological Society, Blue Hill Observatory, Milton, Massachusetts.

Bulletin Officiel du R.A.A., 6, Rue de Mezieres, Paris (6), France.

Bulletin Technique du Bureau Veritas, 31 rue Henri-Rochfort, Paris (17), France.

Canadian Aviation, Journal Building, Ottawa, Canada.

Contact, Fort Lee, N. J.

Deutsche Luftwacht, Schoeneberger Ufer 46, Berlin W35, Germany.

Les Fiches Aeronautiques, 6 rue Galilee, Paris, France.

Flight, Dorset House, Stamford St., London, S.E.1, England.

Flugwesen, Konviktska 22, Prague 1, Czechoslovakia.

Indian Aviation, P. O. Box 2361, Calcutta, India.

Interavia, 13, Corraterie, Geneva, Switzerland.

Journal of Air Law, Northwestern University, Chicago.

Journal of the Institute of Engineers, Australia, Science House, Gloucester and Essex Sts., Sydney, N. S. W., Australia.

Journal of Research of the National Bureau of Standards, U. S. Govt. Printing Office, Washington, D. C.

Journal of the Royal Aeronautical Society, 7 Albemarle St., Piccadilly, London, W.1, England.

Journal of Scientific Instruments, 1 Lowther Gardens, Exhibition Rd., London, S.W.7, England.

Journal of the Society of Automotive Engineers, 29 West 39th St., New York City.

Letectvi, Celetna 13, Praha I, Czechoslovakia.

Luftfahrt-Forschung, Verlag Oldenbourg, Munich 1, Germany.

Die Luftreise, Lindenstr. 35, Berlin SW68, Germany.

Luftfahrt-Literaturschau, Z.W.B. bei der D.V.L., Berlin-Adlershof, Germany.

Model Airplane News, 551 Fifth Avenue, New York City.

Model Aviation, The American Academy for Model Aeronautics, 1733 RCA Building, Rockefeller Center, New York, N. Y.

Monthly Weather Review, U. S. Dept. of Agriculture, Washington, D. C.

Motor and Flying, 24 Bond St., Sydney, N. S. W., Australia.

National Aeronautic Magazine, Dupont Circle, Washington, D. C.

Official Aviation Guide, 608 S. Dearborn St., Chicago.

The Pilot, Grand Central Air Terminal, Glendale, California.

Il Politecnico, Via Spiga 32, Milan (2/7), Italy.

Popular Aviation, 608 S. Dearborn St., Chicago.

Proceedings of Institute of Radio Engineers, 330 W. 42d St., New York City.

Publications Scientifiques et Techniques du Ministère de l'Air, 55, Quai des Grands-Augustins, Paris, France.

Review of Scientific Instruments, 175 Fifth Ave., New York City.

Revista de Aeronautica, Ministerio de la Guerra, Apartado 1047, Madrid, Spain.

Revue de l'Armee de l'Air, 55 quai des Grands-Augustins, Paris, France.

Revue du Ministere de l'Air, 71 avenue des Champs-Elysees, Paris, (8), France.

Rivista Aeronautica, Ministero dell'Aeronautica, Rome, Italy.

The Royal Air Force Quarterly, Gale & Polden Ltd., 2 Amen Corner, London, E.C.4, England.

Schweizer Aero-Revue Suisse, Gubelhangstrasse 22, Zürich-Oerlikon, Switzerland.

Soaring, 1614 Delaware Ave., Wilmington, Del.

Southern Flight, Ledger Building, Fort Worth, Texas. Texas.

Sportsman Pilot, 515 Madison Ave., New York City.

Technical News Bulletin of the National Bureau of Standards, U. S. Govt. Printing Office, Washington, D. C.

Technika Vosdushnogo Flota, Ul. Radio 16, Moscow 16, U. S. S. R.

La Technique Aeronautique, 2 rue Blanche, Paris (9), France.

U. S. Air Services, Transportation Building, Washington, D. C.

Western Flying, 420 S. San Pedro St., Los Angeles, California.

Wirtschaft Technik Verkehr, Alte Jakobstr. 148/155, Berlin SW68, Germany.

Zeitschrift für angewandte Mathematik und Mechanik, Kulmstr. 1, Dresden A24, Germany.

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps.

Aerodynamics

Comprehensive Report on the Lift of Non-Stationary Airfoils. H. G. Kuessner. Results so far obtained concerning the air forces on irregularly movable airfoils for the case of two-dimensional flow are derived from the method of attached vortexes. The report includes the well-known examples of the oscillating flat plate with control surface, and the sudden change of direction of motion, as well as new results on the eddy loss of oscillating plates and the change of circulation when an object enters a slipstream. Luftfahrtforschung, December 20, 1936, pages 410-424. 5 illus. 5 tables. 80 equations.

Derivation of Coefficients of Orifices. W. E. Howland and J. D. Richetta. Mistake in the original derivation of the coefficient of contraction, by the method of Professor Hooper. The method is re-applied to the circular orifice using a slightly different assumption of velocity distribution based upon a compound surface and is extended to the rectangular orifice and to spherical surfaces whose centers are not in the plane of the orifice. A further study was made on the influence of the coefficient of velocity upon the coefficients of contraction and discharge. Journal Franklin Institute, January, 1937, pages 83-94. 5 illus. 6 equations.

Loss of Momentum and Drag. J. E. Serby. Method of measuring the drag by exploration of the wake behind a wing which has been further developed by Professor B. M. Jones and extensively used at the Royal Aircraft Establishment. Local profile drag coefficient of a small part of the wing span and the effect of different surface finishes and of wing thickness can be measured. Theory, method of mounting a "comb" of pitots on the trailing edge of the wing, precautions necessary in flight tests, method of plotting the wake, and accuracy of results obtained are discussed. A saving of about 22 per cent in wing drag was obtained by using a perfectly smooth wing covering instead of doped fabric. Aircraft Engineering, January 1937, page 21. 4 illus. 4 equations.

Motion of a Plate on Entering into a Slipstream. H. G. Kuessner. Test of theoretical assumptions with reference to the aerodynamic forces which are exerted on a plate upon entering a slipstream. A rectangular plate with symmetrical profile was photographed in free fall through the free jet of a wind tunnel. During introduction of the plate into the free jet no moment of measurable quantity was exerted around the neutral point. Luftfahrtforschung, December 20, 1936, pages 425-429. 6 illus. 4 tables. 4 equations.

Guidonia Center of Aeronautical Research. B. Rabinovitch. Laboratories of the Italian aeronautical research center are described with details of the hydrodynamic basin and supersonic wind tunnel. Research undertaken in radio, mechanical construction, acoustics, optics, physical and chemical testing, and aerodynamics is briefly reviewed. L'Aérophile, November 1936, pages 249-251. 4 illus.

The Latest About Skin Friction. B. M. Jones. Profile drag and a new conception of aerodynamic smoothness. Recently acquired information about skin friction is taken up more from the point of view of the practical man who has to use the information, than from that of the research worker. A clearer understanding is given of the boundary layer by which skin friction is applied and experimental technique for its study is described. Paper presented before the Royal Aeronautical Society. Discussion given in the second issue. Aeroplane, Aeronautical Engineering Supplement, December 23 and 30, 1936, pages 805-807 and 836. 9 illus.

The Seventy-First Birthday of the R. Ae. S. Amusing criticisms of films dealing with methods of research at the Royal Aircraft Establishment. Appreciative comments are made on American slow-motion films on bird flight also shown at the Royal Aeronautical Society meeting. "We thought the next film (Royal Aircraft Establishment) was also in slow motion, but eventually discovered that it showed the scientists going about their daily occupations at their normal speed of operation. . . . The films—recorded on inferior stock, with ancient cameras and without reference to existing technique of the cinematographic lighting—showed no item of technical research which we were able to date later than 1926." Aeroplane, January 20, 1937, pages 60-61.

Aircraft Design

Aeronautics in Naval Architecture. C. P. Burgess. Naval architecture and aeronautics are compared to show what each has learned from the other. Design and performance of airplanes, flying boats, airships, hydroplanes, steamships, and sail boats are given with relative advantages of each type. Outstanding performance record of the Graf Zeppelin is cited as proof that the airship is more suitable than the airplane for long-range oceanic transport. Submerged hydrovanes for hydroplanes, seaplanes and flying boats are considered with their advantages and disadvantages. S. A. E. Journal (Transactions), January 1937, pages 13-18. 1 illus. 5 equations.

Let Us Simplicate. Degree of complication gradually creeping into the installation of equipment on military aircraft and the necessity for simplification in case of war. Brief editorial. Flight, January 21, 1937, page 48.

Mass Equlibrium of Control Surfaces. K. Leiss. A control surface can be so balanced by means of a finite number of additional masses of equilibrium that it remains free from rotation for particular vibratory forms of the control-surface axis. Relations for the lowest number of balancing masses to be applied, and their positions and moments are derived. Luftfahrtforschung, December 20, 1936, pages 430-432. 2 illus. 6 equations.

Speed- and Impact-Pressure Distribution in Vertical Dive. F. N. Scheubel. A method is developed for calculating the maximum impact pressures and the maximum speed of airplanes in vertical dives. Luftfahrtforschung, November 20, 1936, pages 371-373. 5 illus.

Theory of the Wing of Particularly Small Finite Span. F. Weinig. As compared with the lift-curve theory usually applied, the decrease of the lift of an airfoil of small span, may be calculated by comparison with a plane grid flow of equal value. Calculated values given are favorably compared with test results. Luftfahrtforschung, December 20, 1936, pages 405-409. 9 illus.

Thousand-Passenger Airliners Forecast at Round-Table Meeting. Aircraft weighing up to 200,000 lb., gaining efficiency as their sizes increase and powered by four-in-line and six-in-line engines within the next five years and huge airliners weighing 1,000,000 lb. and carrying 1,000 passengers in 1950 were visualized by I. I. Sikorsky. Predictions made by others in regard to engines, fuels, aerodynamic efficiency, and airships are also referred to. Brief summary of discussion taking place at the joint meeting of the S.A.E., A.S.M.E., and the Institute of Aeronautical Sciences. S. A. E. Journal, January 1937, page 26.

Two-Dimensional Problem of Wing Vibration. R. Kassner and H. Fingado. Critical speeds for the case of the airplane wing without ailerons and without material damping are accurately calculated by means of the graphical representations of curves given. A relatively simple and accurate method of calculation is presented for the use of designers and, from examples, curves for the design of technically good wings are developed.

A second article entitled "Consideration of Internal Damping for the Two-Dimensional Problem of Wing Vibration," by R. Kassner, gives a graphical method for solving the problem of a wing with internal damping. Luftfahrtforschung, November 20, 1936, pages 374-387 and 388-390. 32 illus. 2 tables. 19 equations.

Progress in Civil Flying-Boats. A. Gouge. Problems overcome in designing three classes of British flying boats, the Calcutta, Kent and Empire, which have come directly under the author's supervision in the last eight years. It is predicted that the Service and civil designs of flying boats will diverge completely in the future and that the Service type is nearing its limit in size although no limit is yet in sight for the civil boat. Materials used in construction and characteristics of the three boats are compared, the limiting take-off weight of the Empire is analyzed, and improvements in performance are explained. The author considers that at present there are no problems to be solved in producing a boat double the weight of the Empire boats, which would have in many respects improved characteristics. Paper presented before the Royal Aeronautical Society with discussion following. Aeroplane, Aeronautical Engineering Supplement, December 16, 1936, pages 771-776. 15 illus. 2 tables. Flight, December 17 and 24, 1936, pages 646-649 and 680-684. 16 illus. 3 tables.

Airplane Design in 1936. E. P. Warner. Operation at higher altitudes, more homogeneous structures, easier handling on the ground, more critical examination and more detailed specification of flying qualities, and smoother surfaces are the current trends in aircraft design discussed. Aviation, January 1937, pages 20, 67-68. 2 illus.

The Future of Aviation. L. Breguet. Speeds of 750 to 780 km. per hour and weights of less than 2 kg. per hp. are predicted for military airplanes of the near future. Future possibilities in aviation in regard to decreased weight in airplanes and engines, influence of weight of engines on speed and altitude, aerodynamic qualities, thermal efficiency of engines, high-speed military and commercial airplanes, and helicopters. L'Aérophile, Special Edition, November 1936, pages 53-58. 4 illus.

Improved Lateral Control. P. P. Nazir. A simple method of sucking away the boundary layer. Apart from its use as a lateral control, the Nazir cut slot and trail flap combination described offers possibilities as a high-lift device. Lift is maintained up to very large angles of incidence (45° or more) indicating a control of the airflow above the wing different from, and more powerful than, any tried hitherto.

Aerodynamic research results obtained at Queen Mary College are discussed covering rolling moment, tests on the rectangular wing, tests proving the lift aileron more powerful than the drag aileron at large incidences, a double wing arrangement, single lift ailerons of various designs, factors of increasing lift, and comparison with other lateral control devices. To be continued. Flight, Aircraft Engineering Supplement, December 31, 1936, pages 36-39, 42. 8 illus.

Stress Analysis and Structures

Aviation. G. Gardner. Progress in metal aircraft construction and functions of the Bureau of Air Commerce. General discussion. Iron Age, January 7, 1937, pages 92-97.

Gust Loads on Airplanes. R. V. Rhode. The gust gradient data used in conjunction with a theoretical consideration of the Wagner effect, and the effect of gust gradient on the vertical motion of airplanes of different size and wing loading are shown to have a qualitative influence on the interpretation of the V-G records. The V-G recorder is described and illustrated and data analyzed which were obtained on the Boeing 247, Boeing 247-D, Douglas DC-2, Sikorsky S-42, Sikorsky S-42A, Sikorsky S-43, Martin 130, Ford 5AT-C, Fairchild FC-2W2 and Fokker F10-A. S. A. E. Preprint for Meeting. January 11 to 15, 1937, 12 pages. 18 illus. on sup. sheets.

Modern Airplane Structures. R. H. Upson. Means of securing weight reductions in aircraft structures, steps in the development of aircraft structures, and specific avenues of improvement still open. Brief outline of paper presented before the Detroit Section of the S.A.E. U. S. Air Services, January 1937, page 34.

What Price Canons"? New multispar wing developed by A. Barclay is claimed to be practically invulnerable to machine-gun fire. Photograph only. Flight, January 14, 1937, page 30. 1 illus.

"Bullet-proof." A new American wing which is being tested by the U. S. Navy. Photograph only. Aeroplane, January 20, 1937, page 73. 1 illus.

Flat Sheet-Metal Girders with Non-Parallel Spars. C. Schmieden. The solution developed in this article for the case of any spar inclination is said to be more accurate than the approximate solution for small spar inclinations offered by Wagner in 1929. Luftfahrtforschung, November 20, 1936, pages 391-393. 4 illus. 24 equations.

A Practical Exercise on the Strength of Rigid-Jointed Frames. Captain J. Morris. A simple test frame is suggested for the student of advanced structures in order that he may check the mathematical prediction of the mode of failure and degree of fixation, and the validity of his basic assumptions. A theoretical investigation of the strength of the loaded frame is carried out. Journal Royal Aeronautical Society, January 1937, pages 9-12. 1 illus., many equations.

Theoretical Determination of Air Forces and Moments on Wings. W. H. Miller and P. M. Magruder. Problem of distributing the air load over the spans of the individual wings of the cellule. Classical methods of hydrodynamics are applied to the calculation of the flow about a monoplane of finite span. Continuation. Aero Digest, January 1937, pages 32, 35, 36. 2 illus. 34 equations.

Aircraft Manufacture

Design for Production. E. P. Warner. Review of papers and discussions presented at the S.A.E. National Aircraft Production Meeting. (See Digest, December 15, for abstracts of these papers.) Aviation January 1937, pages 34-35, 75. 2 illus.

Aircraft Performance

Seaplane Handling. D. J. Brimm, Jr. The technique of water flying. Advice on handling a seaplane while taxiing on the water is given in this issue. To be continued. Aviation, January 1937, pages 31-33. 4 illus.

Some Experiences and Lessons Learned in Spinning Aeroplanes. J. B. Taylor. Phenomenon of spinning, flat spins encountered by the author, Department of Commerce and military requirements in regard to spinning, general rules found to be most effective in recovery from almost all conditions and particularly from a prolonged spin, experience with airplanes with slots, and use of the spin chute are discussed and reference made to N.A.C.A. instruments. The author's experience covers over 5,000 hours flying time in 360 different types of airplanes, and a good many years as naval test pilot. Journal Royal Aeronautical Society, January 1937, pages 1-8.

The Take-Off of Airplanes. Captain C. Mazzoni. Influence of the various factors on the distance for take-off from the ground and a graphical procedure for determining the distance and time necessary for the airplane to leave the ground. Rivista Aeronautica, December 1936, pages 385-393. 7 illus.

Electric Measurement in Timing the Speed of Airplanes. P. Legrain. Principal errors affecting the measurement of airplane speeds and the corrections used in the French system. L'Aérophile, November 1936, pages 254-255. 3 illus.

Keeping Its End Up. Installation of a small parachute in the tail of a Heston Phoenix as a precautionary measure during spinning tests. Photograph only. Flight, December 24, 1936, page 673. 1 illus.

Aircraft

An Engineer at the Paris Show. H. J. Pollard. Comments on the adjustable tailplane used in the Bloch 131 bomber together with what appeared to be trimming strips on the elevator, its forward folding undercarriage, the forward location of power units in French designs, and the super-excellence of engine and other cowls.

Principle of control and operation of the Messier retractable undercarriage and differential braking obtained by hydro-pneumatic control are illustrated.

The Stroborama working in conjunction with a propeller rotating at high speed and its other applications, light Continental alloys, Chobert riveting machine, the Olaer undercarriage retracting device, and the Rollet remote control for carburetor and other operation are discussed. Concluded. Flight, Aircraft Engineering Supplement, December 31, 1936, pages 39-42. 6 illus.

Potential World Aviation. Number of various types of military aircraft of various countries, size of air force and amount of the budget, as well as the passengers, mail and freight transported on their commercial airlines are shown in interesting statistical charts. A few facts concerning some of the military and commercial airplanes of the various countries are given with illustrations. A table of performance and characteristics of these airplanes as well as a table of characteristics of the engines powering them are included. Illustrated descriptions of French airplanes, engines and accessories exhibited at the Paris Aero Show follow. L'Aérophile, Special Edition, November 1936, pages 70-123. Many illustrations.

We Go Abroad and We See the Paris Show. S. P. Johnston. Design trends in Continental aircraft and engines exhibited with references to outstanding products. Brief. Aviation, January 1937, pages 26-27. 10 illus.

The Fifteenth Paris Salon. W. S. Farren. All the most interesting machines exhibited were examples of stressed skin construction in aluminum alloy and the standard of workmanship was everywhere high. Design trends, especially of French aircraft, are analyzed.

Interesting points of the following airplanes are discussed with some criticisms: Potez 63, Bloch 131, Hanriot 220, the two Dutch aircraft designed around armament (Fokker G1 and Koolhoven FK55), Caudron, Mureaux, Morane, Loire-Nieuport, Farman, Pou-de-Ciel, and the L'Aile Volante.

The critical review of engines exhibited refers principally to the radials and to the horizontally-opposed Lorraine engine. Aircraft Engineering, January 1937, pages 3-8. 14 illus.

Belgium

The S. E. A.-1 Commercial Bimotored Airplane. The bimotored Belgian monoplane described may be used either as a commercial airplane for transport of passengers and mail, or as a military airplane for supply, attack, coastal defense, and bombardment. For attack of troops at low altitudes, the airplane is armed with two machine guns. With a load of 8 bombs of 50 kg. and crew of two it has a range of 750 km. Maximum speed is 280 km. Rivista Aeronautica, December 1936, pages 431-433. 2 illus. 2 tables.

France

The Four Winds. Caudron has completed a light fighter monoplane, known as the C.170 or Requin, and fitted with a 450-hp. Renault inverted-vee twelve-cylinder engine. It should be capable of over 300 m.p.h. Brief reference. Flight, January 21, 1937, page 53.

The Lioré 47. Weight, take-off time, and wing loading recorded in tests of the new 17-ton four-engined Lioré et Olivier 47 boat. Brief reference. Flight, January 14, 1937, page 38.

Tails Up! A startling type of aircraft (fuselage in vertical rather than horizontal position) was designed by C. de Rouge and successfully tested at Toussus le Noble, France. Photograph only. Flight, January 7, 1937. 1 illus.

The Amiot 144 Bimotored Bomber. The Amiot 144 transports 1,000 to 2,000 kg. of bombs and has a range of 4,000 km. Design, various positions and arrangements of armament, performance, and bomb loads are described. Illustrations of the Amiot 142 and 143. Rev. de l'Armée de l'Air, August 1936, pages 945-952. 12 illus.

The Four Winds. It is reported that the Marcel Bloch 160 (four 690-hp. Hispano X engines), the new Makhonine with retractable outer wing panels, and the Amiot 341 have been entered in the New York-Paris Race.

New Romano light fighter biplane, said to be unusually interesting, has wheels retracting into the fuselage, gull-type upper wings, a span 3 ft. shorter than its fuselage, and 450-hp. inverted-vee Renault engine. It should do 285 m.p.h. and, cruising at 200 m.p.h., the range should be about 500 miles. Brief references. Flight, December 1936, page 695.

A Franco-Russian Alliance. Makhonine retractable wing now being built for the French government. Photograph only. Aeroplane, December 23, 1936. page 808. 1 illus.

Modern French Airplanes. M. H. Desbruéres. Characteristics and performance of French military and civil airplanes tried out during 1935. Abstract from Science et Industrie. Rivista Aeronautica, November 1936, pages 225-235. 15 illus. 2 tables.

Potez 65 Monoplane for the Transport of Troops. Monoplane designed for colonial service to be used as a transport for 14 armed soldiers, food and ammunition supplies, or airplane and engines parts, as a bomber carrying bombs of 10,100 and 200 kg. or as an ambulance. It has a useful load of 1810 kg., a top speed of 300 km. per hour, at 2000 m. and a range of 1200 km. Characteristics, performance, and design described. Rivista Aeronautica, November 1936, pages 257-265. 8 illus. 2 tables.

Germany

For the German North Transatlantic Service. The Hamburger Ha 139 monoplane built for Luft Hansa is to be catapulted like the Dornier boats. It has four 600-hp. Jumo 205 Diesel engines, a top speed of 186 m.p.h., and a range of 3100 miles and weighs more than 15½ tons. Photographs only. Aeroplane, January 13, 1937, page 38. 4 illus.

A New German Fighter. One of the latest Heinkel middle-wing two-seaters in which the pilot is seated between the spars and the gunner behind the rear spar. Photograph only. Aeroplane, January 13, 1937, page 31. 1 illus.

German Military Aircraft. P. M. Magruder and L. Zacharoff. Various training planes, fighters, fighter-bombers, and naval and seaplane types now in active use are described in a digest of types, constructional features and performances. Glider and engine development is also mentioned. The most important factor in Germany's rearmament of her air force is said to be the systematic development of raw materials, pilots, engineers, and aircraft factories designed solely for mass production on short notice. Aero Digest, January 1937, pages 24-28. 15 illus. 1 table.

A German Trainer. Weihe, or Kite, Focke-Wulf FW-58 low-wing monoplane of high aspect ratio with retractable undercarriage and two Argus As. 10C. inverted-vee 240-hp. engines. The airplane is primarily intended to train pilots of large twin-engined airplanes but can be readily adapted to give radio and blind-flying training, or for military training of gunners and bombers. For the latter application, a longer nose is put on which contains positions for a forward gun and prone bombing, the change being made quickly by undoing a few screws. A second gun position is built into the top of the fuselage behind the pilot's cockpit. Top speed is 156 m.p.h. Aeroplane, December 30, 1936, page 834. 2 illus.

On the German Aircraft Industry. C. G. Grey. An entertaining account of a visit to the Henschel Works with reference to air-raid shelters for the workers, and the dive bombers, a visit to the Heine propeller factory and its method of manufacturing propellers, and comments on the German aircraft industry as a whole. The Henschel dive bomber, short reconnaissance monoplanes, and trainers are illustrated. Continuation. Aeroplane, December 16, 1936, pages 777-780. 7 illus.

GREAT BRITAIN

For Aeroplanes Only. Babs. An entirely humorous and satirical article on conservative British airplanes. Aeroplane, December 23, 1936, pages 791-792. 5 illus.

Smaller Arenas? The production-type Gloster Gladiator single-seater fighter (795-825-hp. Bristol Mercury IX) has flaps on the upper and lower wings and an enclosed cockpit. Maximum speed is 255 m.p.h. at 14,500 ft. Photograph only. Flight, January 21, 1937, page 53. 1 illus.

British Commercial Aircraft. Main characteristics and scope of current types and their capabilities in the commercial field. Products of eighteen companies. Flight, January 21, 1937, pages 63-70. 20 illus. 1 table.

Imperial Ensigns. Structural details of the new Armstrong-Whitworth A. W. 27 40-passenger four-engined monoplane of highly-developed light-metal construction. The monoplane has a gross weight of approximately 20 tons, a top speed of 200 m.p.h., and a cruising speed of 160 m.p.h. The fuselage is built like a flying-boat hull. Flight, January 7, 1937, pages 8-10. 15 illus.

The Latest Version. Newest Fairey Battle equipped with a Rolls Royce Merlin, the new top, and knee-caps on the landing gear, and the Armstrong Whitworth medium bomber-fighter which has an 880-hp. Siddeley Tiger engine. Photographs and brief comparison. Aeroplane, December 16, 1936, page 770. 5 illus.

The Fairey Battle, Armstrong Whitworth P. 27/32 medium bomber, and Fairey reconnaissance seaplane. Photographs only. Flight, December 17, 1936, pages 649, 651, 663. 4 illus.

A New Class of Aircraft. The new Cameron rotor plane described seeks to combine in one aircraft all the desirable qualities of the airplane, autogiro, and helicopter. The rotor blades are retractable. The plane can take off with a run, like an airplane, it can make a "jump start," or it can rise vertically as a helicopter. Two ways have been provided for preventing the whole aircraft from rotating around its vertical axis in a direction opposite to that in which the rotor is being driven. A very ingenious gear arrangement is used for driving the rotor direct as in "jump starts" or helicoptering. Flight, December 31, 1936, pages 705-706. 4 illus.

The Year That Has Passed. "Adoption of completely modern methods of construction and further aerodynamic refinement, coupled with the use of the most advanced, high-powered aero-engines in the world has given us, during the past year, the finest military prototypes in existence." A brief outline of British military aircraft with the comment that the Bristol Blenheim is, without doubt, the fastest twin-engined bomber in production. Notable British flights and flying events of 1936, civil aircraft developments, British engines of 1936, and the year in air transport. Flight, December 31, 1936, pages 690-694. 11 illus. 1 table.

HOLLAND

Fokker G.1 Attack Airplane. A. Frachet. Two-place monoplane of mixed construction may also be used as a light bomber or reconnaissance airplane. The airplane is equipped with two Hispano Suiza 750-hp. or Bristol Mercury VII 830-hp. engines, has a top speed of 470 km. per hour when powered with the latter and a range of 1550 km., and climbs to 1000 m. in 1 min. 6 seconds. The fuselage nose carries two "canons" of 23 mm. and two machine guns. Long description of design, characteristics, armament, and performance. Les Ailes, December 10, 1937, page 3. 4 illus.

Koolhoven Junior F K 53 Monoplane. Light two-place sport plane with a top speed of 150 km. per hour and range of 1300 km. Characteristics and performance. Rivista Aeronautica, November 1936, pages 265-267. 3 illus. 1 table.

ITALY

The Airplane with Oscillating Wing. A. Jona. Approval tests successfully passed by the Jona J.6 airplane with oscillating wing proved how effectively the airplane may be controlled in all evolutions by the single bar and that the airplane cannot crash in spinning or side slip of the wing. Design and the directional, lateral and longitudinal stability of the airplane in flight tests are described. Future applications of the design to multimotored sesquiplanes, single-engined monoplanes with a fixed horizontal plane, and multimotored monoplanes with propellers rotating in a direction inverse to that in normal use are outlined. Rivista Aeronautica, December 1936, pages 360-368. 6 illus.

U. S. A.

The Four Winds. The North American O-47 observation monoplane has transparent panels beneath the mid-wing for the observer. Brief reference. Flight, January 7, 1937, page 11.

Something New from America. Consolidated P.30 two-seat fighter powered by a Curtiss Conqueror engine. Photographs and a reference to the exhaust-driven supercharger arranged on the port side. Aeroplane, January 13, 1937, page 46. 2 illus.

And Next—the Tricycle Gear. F. Miller. Success of Army tests of the tricycle-type three-wheel landing gear, its use on the Douglas DC-4 four-engined super airliner, early applications of this type of landing gear, and recent applications in the Stearman-Hammond and Waterman airplanes. Aviation, January 1937, pages 8-10. 7 illus.

Douglas D F Flying Boat. The thirty-two passenger Cyclone-powered flying boat described has a range of 3,280 miles, and a high speed of 185 m.p.h. at 6,500 ft. Construction, weights and performance with details of the flotation-type beaching gear used with it. Aviation, January 1937, pages 37-38. 8 illus.

Heat Blisters. "Defensive armament of the Boeing Y B-17 bomber, the first of thirteen for the U. S. Army Air Corps, is carried in a novel nose turret, and four streamlined blister-like emplacements whence, so it is said, 'the heat can be turned on' in practically all directions." Photograph with brief reference. Flight, December 31, 1936, page 688. 1 illus.

Larger Flying Boats. New 60-passenger Boeing Clippers for Pan American. A few details. Scientific American, January 1937, pages 34-35.

North American's New Bomber. The North American Dragon twin-engined bomber has been built for service in the substratosphere and is said to be almost invulnerable from even large-caliber gun fire. Defensive armament is so arranged that from three to five high-powered guns can be brought to bear on any point around the airplane. Gun mounts are of a new type to permit the operator to work efficiently a high altitudes. Bomb load is said to be the largest provided for any airplane to date. The bomber will be entered in the competition at Dayton in March. Design details. Western Flying, January 1937, pages 10, 28. 1 illus.

Twin-Engined Beechcraft M 18. Low-wing monoplane of metal semi-monocoque construction with electrically retracting landing gear (including tail wheel) and accommodations for six passengers and two pilots. The airplane is powered by two Wright 420-hp. engines and has a cruising speed of 185.5 m.p.h. at 11,500 ft. Construction, equipment, specifications, and performance with Wright and Jacobs engines. Aviation, January 1937, pages 40-41. 3 illus. Western Flying, January 1937, pages 21, 44. 1 illus.

U. S. S. R.

The Four Winds. First two of the sixteen monoplanes of the improved Maxim Gorky type with six engines of 1200 hp. each are nearly finished. Sixty passengers and a crew of eight will be accommodated in comfort. Brief reference. Flight, December 24, 1936, page 673.

Stalin' of Multi-Cellular Wings. Sixteen workers were borne aloft in the thick-section lower wings fitted to a Russian R-5 two-seater with 600-hp. engines. Designer Grokhovsky hopes to use the system for freight carrying. With the sixteen passengers the airplane took off from snow in 30 seconds and attained 126 m.p.h. Photograph only. Flight, December 24, 1936, page 673. 1 illus.

Airships

A Test of the Helistatic Devil. M. S. Ducout. The small airship of 600 cu.m. described has a lifting propeller under the nacelle which is operated by a 12-hp. engine and permits complete control of the climbing and horizontal speeds. Results of a test, characteristics, and performance. L'Aérophile, November 1936, page 253. 2 illus.

Air Transportation

A Year's Air Transport in Retrospect. F. D. Bradbrooke. German triumphs, British developments in airports, flying and ground equipment, and accidents. Aeroplane, January 6, 1937, pages 19-21. 2 illus.

Air Transport in 1936. Colonel E. S. Gerrell. Happenings and developments of the year. Aviation, January 1937, page 24. 2 illus.

The Final Link. H. A. Taylor. Past, present and future of the trans-atlantic project with a drawing of a globe showing airship courses, south Atlantic aircraft courses, and possible aircraft courses in the north Atlantic. The direct route between Ireland and Newfoundland will probably be adopted with the Azores-Bermuda route as an alternative. Reference to the Cavalier which has been shipped to Bermuda, the Short-Mayo composite machine for launching airplanes, preparations, Diesel advantages, and the recent success of the Germans with this engine. Flight, December 24, 1936, pages 668-672. 7 illus.

Two French Air Bases in North America: St. Pierre and Miquelon and the Antilles. Captain J. Pouyer. Possibilities of establishing a transatlantic airway from France to these points and meteorological conditions to be encountered. Rev. du Ministère de l'Air, October 1936, pages 1260-1277. 11 illus.

Propellers

The Constant-Speed Propeller. F. W. Caldwell, E. Martin, and T. B. Rhines. Effect of constant-speed propellers on performance calculation, flight testing, and airplane performance. Various types of automatic controllable-pitch propellers are discussed and it is shown that constant-speed operation will give the most satisfactory airplane performance. Aerodynamics of the constant-speed propeller and certain new performance possibilities that will result from this type of performance are described. Reference is made to mixture control with constant-speed propellers and propeller vibration.

In a second article (by E. Martin and C. F. Baker) the development work resulting in the Hamilton standard constant-speed control is reviewed and the various types of controls evolved during that development are discussed. The present control is described in detail as to both design characteristics and operation in conjunction with the propeller. S. A. E. Journal (Transactions), January 1937, pages 28-33 and 34-44. 27 illus. 9 equations.

Engine Design and Research

Characteristics of Diesel Aircraft Engines at Altitudes. M. Précoul. The Diesel engine is much more sensitive to atmospheric conditions than other types of internal-combustion engines, according to the data given. Effective pressure variations with altitude for mixtures of constant and variable composition and variations of r.p.m., torque, power, fuel consumption, and compresson ratio with altitude are discussed. Results of altitude tests of Diesel aircraft engines are given. La Technique Aéronautique No. 141, 1936, pages 210-256. 19 illus. 10 tables. 60 equations.

Characteristics of the Two-Row Radial Engine. R. Insley. Combined weight of cowling, baffles, and exhaust collector is no greater for the two-row engine than for the corresponding single-row. Weight, improved operating characteristics, reduction in propeller stresses, noise and cost reductions, servicing, cooling, and overall dimensions are compared with those of the single-row engine and particular reference is made to the Pratt and Whitney Twin Wasp and Twin Wasp Junior. Aero Digest, January 1937, pages 46, 48. 5 illus.

Engine Temperature as Effecting Lubrication and Ring Sticking. C. G. A. Rosen. Diesel ring-sticking problem investigated by the Caterpillar Tractor Company. Tests results discussed cover: The combustion process; design characteristics of liner, piston and piston ring; metallurgical factors as affecting rubbing surfaces; machining operations as influencing lubrication; break-in and testing procedures as determining surface conditioning; and the operation of a number of lubricants generally considered suitable for Diesel engines. S. A. E. Preprint for Meeting, January 11 to 15, 1937, 11 pages. 4 illus. 1 table.

Compression-Ignition Engine Performance at Altitude Conditions. C. S. Moore and J. H. Collins, Jr. Altitude performance of both a supercharged and an unsupercharged compression-ignition engine compares advantageously with that of a carburetor engine, and the low temperatures of altitude are especially important in maintaining altitude power of the former. Methods are given for correcting maximum unsupercharged performance when maximum cylinder pressure does not limit output, and maximum boosted performance with conservative maximum cylinder pressures.

N. A. C. A. tests on a compression-ignition engine for various combinations of inlet-air temperature and pressure to simulate altitude conditions are described and results obtained by this approximate method are compared with those secured in the Bureau of Standards altitude chamber. Details of the test unit, test conditions, and the air-conditioning equipment are given. The approximate method of making altitude tests has been used for some time by the Naval Aircraft Factory for testing carburetor engines. S. A. E. Preprint for Meeting, January 11 to 15, 1937, 10 pages. 17 illus. on sup. sheets.

Engine Design in 1936. C. F. Taylor. Increasing use of the two-row radial, increasing proportion of inline engines for the smaller airplanes, continued upward trend in take-off power and piston speeds, general trend toward lowered fuel consumption, improvements in cooling and cowling of radial engines, non-icing carburetors for large radial engines, Diesel engines, development of ultra-high-speed airplane engines with a large number of small cylinders, and engine-vibration research are referred to. Aviation, January 1937, pages 21-67. 2 illus.

Ignition Shielding of Aircraft Engines. J. Malczewski. Shielding of the magneto, casing of the shielded ignition, and shielding of the spark plugs are discussed. L'Aérophile, November, 1936, pages 259-260. 4 illus.

High Output and How? R. N. DuBois and V. Cronstedt. Possibilities of the high-octane fuels from the standpoint of the engine designer who might be permitted to start from scratch and proceed to develop his basic design around these fuels. The discussion covers: theoretical thermal considerations; results of some cylinder calibrations at two compression ratios and with fuels ranging from Air Corps Y-3557 fuel of 87 octane by the motor method, to iso-octane plus 3 c.c. of tera-lead; mechanical considerations and the speed factor; and design of cylinders, valve gear, connecting rods, bearings, crankshaft, crankcase, super-charger drive, accessories drive, and propeller reduction gear to meet the high gas pressures, severe thermal conditions, and high dynamic stresses developed with high-octane fuel. Experience gained during work done for the U. S. Army Air Corps. S. A. E. Preprint for Meeting, January 11 to 15, 1937, 22 pages. 17 illus.

Main Session of the Lilienthal Gesellschaft. A. E. Thiemann. "Development of Bearings for the Daimler-Benz Diesel Engines of the L. Z. 129," Nallinger. "Further Development of the Junkers Diesel Engines for Aircraft," Gerlach and Gasterstaedt. "Airplane Engines and Their Problems of Operation," Arthur Nutt. Brief abstracts of the first two papers and long abstract of the last. A. T. Z., December 10, 1936, pages 587-592. 17 illus.

Piston Temperatures in a Sleeve-Valve Oil Engine. H. W. Baker. Three pistons of markedly different characteristics were tested, the first of cast iron with the crown tapering slightly away from the center, the second of L 8 alloy, the shape inside being roughly parabolic, the third of Y alloy identical in weight with the second but with an entirely different distribution of metal. Pistons tested, test engine, and built in thermocouple junctions used are described. Pistons were of intermediate size and were used at speeds up to 1400 r.p.m. Paper presented before the Institution of Mechanical Engineers. Engineering, January 22, 1937, pages 107-108. 7 illus. 2 tables.

A Visual Study in a Displacer-Piston Compression-Ignition Engine. A. M. Rothrock. To observe the effects of a displacer piston on air flow and effects of air flow on the fuel spray and flame formation, high-speed motion pictures were taken at the rate of 2200 exposures per second in the combustion chamber of the N.A.C.A. combustion apparatus. Although the core of the fuel spray was not destroyed by the air movement, direction of the spray was changed and the spray envelope was carried away by the moving air. Air movement set up during induction of air into the engine cylinder could be controlled so as to materially aid in the air flow set up during the last of the compression stroke. Apparatus and results described. S. A. E. Journal (Transactions), January 1937, pages 22-27. 7 illus.

Engine Manufacture

Engine Design and Production Hold the Spotlight. Ring-sticking problem, close machining practice, ring sticking in aircraft engines, new temperature-measuring spark plug, boosting aircraft-engine output, oiling the hypoid rear axle gears, truck, bus and railcar, the low-down on Diesel upkeep, controlling the production dollar, and effect of knock level in fuel tests are discussed. Abstracts of papers presented before the S. A. E. (Preprints of most of the above papers obtainable from Editorial Unit). Automotive Industries, January 23, 1937, pages 112-119. 10 illus.

Machinery and Methods in Engine Production. Layout of the plant of the Ranger Engineering Company, equipment, and routing of the work through the plant. Aero Digest, January 1937, pages 21-23. 9 illus.

Engine Testing

A Sparking Plug, Adapted for Measuring Cylinder Head Temperatures. G. D. Boerlage and A. G. Cattaneo. Temperature registered by the device described is practically equal to that of the combustion chamber wall and varies accordingly without appreciable time lag. The high tension and the temperature-measuring circuit are completely separated. The device has been in use at the Royal Dutch Shell Engine Research Station in tests on aviation engines. The insulated thermocouple wires are introduced through two holes in the body of the spark plug and brought into contact with each other in the rim pointing towards the combustion chamber and lying flush with its surface. Two other methods are also described and results obtained in tests of both water-cooled and air-cooled engines are given. S. A. E. Preprint for Meeting, January 11 to 15, 1937, 6 pages. 5 illus.

Engines

1220-Hp. Wright G-100 Cyclone Engines for Commercial Airlines. Developed for commercial airline use, the G-100 Cyclone produces 1220 hp. at 2400 r.p.m. and incorporates a reduction gearing set at 16:11. Improvements in design are briefly described and reference made to the new Wright test building. Aero Digest, January 1937, page 42.

Engines of 1936. Development of British aircraft engines has been along the lines expected but next year should see new engines in full production. Brief outline of British engines and airplanes to be powered by them. Flight, December 31, 1936, pages 692-693. 2 illus.

From Petrol to Oil Fuel. A simple conversion of a Cirrus II engine from gasoline to Diesel fuel. The Finnish invention applied permits the use of Diesel fuel in a more or less orthodox gasoline engine. Oil is vaporized to a suitable degree and then fired by spark plug in the normal manner. A ring of special iron alloy, ½-in. thick, is interposed between each cylinder head and barrel. Inside the ring are six sloping vanes or baffles which catch and vaporize the Diesel oil from a three-nozzle injector, the arrangement being such as to produce efficient turbulence horizontally around the cylinder. Flight, December 24, 1936, page 678. 2 illus. Aeroplane, December 23, 1936, page 808. 2 illus.

The Gnôme Rhône 14 N Engine. Fourteen-cylinder radial air-cooled engine described develops 950 hp. at 2350 r.p.m. at 3800 meters. Rivista Aeronautica, November 1936, pages 270-273. 3 illus. 1 table.

Shown in Paris. Walter Major VI 205-hp. engine, Train 60-hp. engine, Renault 425-hp. engine, C.C. 4 two-stroke 65-hp. engine of the L'Aile Volante, Regnier 265-hp. engine and the Walter Anton 28-hp. engine. Photographs only. Aeroplane, December 30, 1936, page 835. 7 illus.

Technical Notes. A new Lorraine engine without valves is being designed. Brief reference. Les Ailes, December 10, 1936, page 5.

Commercial Aircraft Engines. Characteristics of engines produced by nine British companies. Flight, January 21, 1937, pages 80-82. 10 illus.

Engines. Renault Models 4-Pgi, 4-Pei, 6-QO1, 6-QO3, 6-OO5, and 12-RO1 aircooled inline and vee, and 9-FAS, 9-FARS, 14-TOO, and 14-TO2 radial aircooled engines. Construction, performance, supercharging, fuel supply, ignition, lubrication, overall dimensions, weight, and power curves. La Technique Aéronautique No. 141, 1936, pages 170-189. 40 illus.

Modern "Six." De Havilland Gipsy Series II 6-cylinder inline inverted aircooled engine. Extensive refinements and the "1000" type variable-pitch propeller developed are described. The supercharged engine was run for twenty hours at 2600 r.p.m., the output being 309 hp. with 4-lb. boost. At even higher r.p.m. and approximately the same boost the power was 325 hp. Long well-illustrated description. Flight, January 7, 1937, pages 12a-12c. 5 illus. Aeroplane, January 6, 1937, pages 15-18. 13 illus.

The New Perkins Oil Engine. Modified injection system with a three-hole nozzle which is illustrated may be of interest. The Leopard 11 4-cylinder oil engine develops 75 b.hp. at 2400 r.p.m. Automobile Engineer, January 1937, page 24. 2 illus.

Parts and Accessories

An Interesting Fuel Pump. KM4a fuel pump produced by the Korect Depth Gauge Company is a compact self-contained unit of the double-diaphragm type capable of deliveries ranging from 1050 to over 1200 pints per hour with lifts of between 3 and 10 ft. against a delivery head of 6 ft. Weight is approximately 4¾ lb. Short description. Flight, December 17, 1936, page 664. 1 illus.

Oil-Cooler for Airplane Engines. Gallay two-stage oil cooler for the lubrication systems of airplane engines. Oil circulates continuously through cooling tubes of large diameter located in the front portion of the cooler. Very brief. Automotive Industries, December 26, 1937, page 894.

Phosphor Bronze Aero Engine Valve Guides. Valve guides manufactured by Thomas Bolton and Sons, Ltd., for the Bristol Aeroplane Company. Photograph and brief reference. Metal Industry, December 25, 1936, page 633. 1 illus.

Preheating Engine Oil. The Eltron electric immersion oil heater referred to has ring-type elements and a temperature feeler rod with a small bi-metal circuit breaker in the point which immediately cuts off the supply current when the oil reaches the predetermined temperature. Heaters of this type are used for heating oil for the German and Russian airplanes. Flight, December 31, 1936, page 694. 1 illus. Two types described. Aeroplane, December 30, 1936, page 843. 2 illus.

Protective Coatings for Automotive Ignition Cable. J. Delmonte. Standard type of construction for ignition cable, lacquered braid protective coating, and tests which manufacturers specify for installation of automotive ignition cable. Brief. India Rubber World, January 1, 1937, pages 43-48. 1 illus. 1 table.

Fuels and Lubricants

Development of an Altitude Knock Test Method. W. M. Holaday and G. T. Moore. Experience with the C.F.R. engine and test method has shown that the method is not sufficiently accurate to permit the use of one sample to indicate the reliability of correlation between two or more engines. Recommendations are made for work to be carried out by laboratories at high altitudes. Results are given for a number of knock-rating tests conducted to criticize the method. A diagram of an engine hookup for development of an altitude detonation test method is included. Work of the Standard Oil Company of Indiana. S. A. E. Preprint for Meeting, January 11 to 15, 1937, 7 pages. 4 illus. on sup. sheets. 5 tables.

Factors Affecting the Relative Knocking Characteristics of Motor Fuels in Service. J. M. Campbell, W. G. Lovell and T. A. Boyd. The tests described indicate that the apparent "depreciation" observed with a particular combination of reference fuels and test fuels may be controlled by a suitable control of the engine speed at which the fuels knock. Effects of mixture ratio and fuel volatility are also discussed. S. A. E. Preprint for Meeting, January 11 to 15, 1937, 5 pages. 5 illus. on sup. sheets.

Influence of Humidity on Knock Ratings. J. R. MacGregor. The method described for controlling humidity has proved satisfactory and should be found so in other laboratories in which the normal range of humidity does not exceed a value of more than about 0.015 lb. water per pound of dry air. A standard of 0.0135 lb. water per pound of dry air in all knock rating tests is suggested. Humidity range in the United States, conventional methods of measuring humidity, an engine hygrometer developed for indicating humidity of the air actually entering the engine, an experimental air drier used to obtain humidities lower than those prevailing in the laboratory, humidifier used on engines in the Standard Oil Company of California laboratory, results of exploratory tests on the influence of humidity on detonation and the influence of two methods of changing dry-air pressure, tests by direct matching, and humidity control in routine testing are discussed. S. A. E. Preprint for Meeting, January 11 to 15, 1937, 11 pages. 10 illus. on sup. sheets.

Fuels and Modern Aero-Motor Design. F. R. Banks. "The U. S. Army Air Corps have done a considerable amount of work on gasoline injection. Apparently the cost is about five to six times as much as that of the carbureter system." The Air Corps knock-testing and fuel-rating methods are also discussed.

Reference is made to the British Air Ministry specification for 100-octane fuel, on the lines of that originally brought out by the Air Corps, which has been issued to get data and experience and to let the British engine builders show what they can do with it.

The discussion covers: the present fuel position, fuel rating and correlation, cylinder heads, valves, exhaust pipes and collector rings, sparking plugs, cold corrosion, light-alloy fuel tanks, application of high-octane fuels, modern power ratings, gasoline injection, fuel consumption, and present-day types of engine. The author's suggestion for a 16-cylinder flat liquid-cooled engine is illustrated. Paper presented before the Royal Aeronautical Society, Institution of Petroleum Technologists and Institution of Automobile Engineers with discussion following. Aeroplane, January 13, 1937, pages 39-46. 12 illus.

Great Britain is said to lead the world as far as supercharging is concerned but credit is given to the Americans for teaching the importance of fuel quality and antiknock value.

Long abstract of the preceding paper reviewing latest fuel developments and the engine problems involved. Iso-octane production, engine developments, valve burning, application of 100-octane fuel, reduced fuel consumption, proposed flat type of engine with two banks of eight horizontally-opposed cylinders, and air versus liquid cooling are discussed. The low-speed engine with large cylinders working at relatively high b.m.e.p. is considered more critical to fuel quality (antiknock value) than the equivalent British types.

A brief editorial is against the adoption of 100-octane fuel for aircraft engines in Great Britain inasmuch as the necessary supplies might not be available in case of war. Flight, January 14, 1937, pages 28-29 and 24. 2 illus.

An Air Ministry specification is being issued for 100-octane fuel although no news has come to hand that any British aero engine has been re-rated to use this new fuel. Brief reference. Flight, January 14, 1937, page 30.

High Octane Fuels. E. L. Bass. Conditions governing the use of high-octane fuels in engines for commercial aircraft. The discussion covers: experiments made to determine improvement in power output and economy; effect of changing engines from 87 to 100 octane fuel; testing of high antiknock-value fuels, including present methods and fuel-testing engines; full-scale engine tests made by the British Air Ministry; and change in design of engines needed. Appendixes deal with the influence of calorific value on the economic value of aviation fuels, compression-ignition engines for aircraft, effect on fuel cost of changing engines of a given aircraft, and effect on fuel cost of altering the design of aircraft to accommodate the more powerful engines available with 100 octane fuel. Paper presented in Paris in connection with the Journées Techniques Internationales de L'Aéronautique. Aircraft Engineering, January 1937, pages 13-18. 6 illus. 9 equations.

Acoustics

Developments in Aircraft Sound Control. H. H. Bruderlin. Problems of weight, moisture absorption, heat insulation, and cost in reducing noise and vibration in airplane cabins and their solution in the design of the Douglas DC-4 40-passenger airplane. The discussion covers the effect of curvature of the fuselage walls on sound transmission, water-proofing the fuselage skin, windows to reduce heat transmission, clearance between propeller tip and side of the fuselage, reduction of beats between engines and propeller reduction gear, engine mounting, and shock-mounting and isolation of cabin floors are referred to. An average noise level of less than 63 decibels above one millibar is expected in the cabin of the DC-4. Journal Acoustical Society America, January 1937, pages 181-184.

Airport Equipment

All-Steel Hangars in France Have Suspended Plate Roofs. New type of hangar with steel frame, walls, and roof said to be of military value because it is quickly erected and easily dismantled for re-use. Brief description. Engineering News-Record, January 14, 1937, page 49. 2 illus.

Airplane Factory Has Long-Span Roof Trusses. Boeing Aircraft Company assembly plant consists of one room 204 x 304 ft. in plan, unobstructed by columns, and 35 ft. high to the lower chords of the trusses. A roof of five 10-ft. saw-tooth monitors is supported by seven of these 44-ton trusses. Brief description. Engineering News-Record, January 21, 1937, page 111. 1 illus.

Airport Construction and Equipment. Brief reviews of displays at the British Airports Exhibition. Flight, January 21, 1937, pages 71-78. 14 illus.

Movable Hangars for a Campaign. M. Aimond. Prncipal characteristics of movable hangars for a campaign and two types of detachable hangars developed by the Société Industrielle des Constructions and the Société des Bases Aériennes. Abstract from Science et Industrie. Rivista Aeronautica, December 1936, pages 414-418. 3 illus.

Ice Formation Prevention

Some Notes on Icing. "Even in the United States, where the aeronautical people are thought to be more intelligent than elsewhere, they have not altogether solved the problem." A few notes on what is being done in Great Britain in the way of de-icing devices for airplanes with a reference to personal experiences with ice deposits on automobiles. Aeroplane, January 13, 1937, pages 37-38.

Metals

Aircraft Engine Materials. J. B. Johnson. Chemical composition, mechanical properties, and applications of steel, aluminum, magnesium, copper and beryllium alloys used in aircraft-engine construction. Mechanical tests, heat treatment, coatings, corrosion and heat resistance, and the selection of materials for various engine parts to meet certain operating requirements are discussed. S. A. E. Preprint for Meeting, January 11 to 15, 1937, 14 pages. 1 illus. 2 tables.

The Nickel Industry in 1936. R. C. Stanley. Nickel alloys, such as Inconel and Monel, used in British aircraft and engines are briefly referred to in a general discussion. Metal Industry, January 8, 1937, page 31.

Heat Treating

Heat Treating Large Aircraft Parts. J. K. Ball. Methods used by the Boeing Aircraft Company. Abstract of paper presented before the S.A.E. Heat Treating & Forging, December 1936, pages 629-632. 1 illus.

Non-Ferrous Alloys

Aluminum in Aircraft Design. T. Woolsey. Production of aluminum, properties of aluminum alloys, classification of these alloys, and their applications in aircraft construction. Aviation, January 1937, pages 14-15. 2 illus. 1 table.

Production of Composite Aluminum Alloy Pistons. In order to take advantage of the low thermal expansion of silicon-aluminum alloy pistons and at the same time to increase the resistance of the piston head to heat, Elektronmetall A.G. has recently produced a composite piston of silicon-aluminum and certain copper-aluminum alloys. It is claimed that perfect bonding is obtained between the matrix and the insert and micro-examination shows that inter-diffusion occurs between the Cu Al_2 crystals of the latter and the silicon crystals of the former. Few details only. Metal Industry, December 18, 1936, page 612.

Alloys of Beryllium and of Magnesium. C. H. Desch. Recent work carried out on magnesium and other light alloys for aircraft construction. Disappointing results were obtained with beryllium in regard to its ductility and combination with magnesium. Brief abstract of paper presented before the Royal Aeronautical Society. Engineering, January 22, 1937, page 100.

Meteorology

Meteorology 1936-1950. P. Wehrle. The future of meteorology applied to aeral navigation. L'Aérophile, Special Ed., November 1936, pages 49-52.

A Receiver for Radiometeorographs. A. V. Astin and L. L. Stockmann. The receiver described is based on the Jones 5-meter superheterodyne receiver and has given satisfactory performance for about a year. It is designed for the reception of pulse-type signals and has a low response to random noises. Rev. Scientific Instruments, December 1936, pages 462-463. 1 illus.

Navigation

Q.E.D. by C.D.C. Two special problems of aerial navigation which may be solved by means of the C.D.C. method. Flight, January 14, 1937, page 38. 2 illus.

Radio

Aero Radio Digest. Newest developments in the field of aircraft radio are described, including the Simon Radioguide, Lear motoreel, United Air Lines method of guarding antennas, and the R. C. A. crystal attachment. Aero Digest, January 1937, pages 56-58. 3 illus.

Four Beacons at Croydon. The Lorenz, Plessey and Marconi ultra-short-wave radio beacons have been installed at Croydon for the British Air Ministry tests and the medium-wave beacon has been

modified for aural operation. Few details. Flight, December 24, 1936, page 686. Aeroplane, December 23, 1936, page 809.

Lear Motoreel. Lear remotely controlled antenna reel said to reduce radiation losses in radio transmitters. Brief description. Aviation, January 1937, page 39.

The "Multi-Net" System of Radio Telegraphy. Captain R. Luce-Catinot. Importance of a number of fixed radiotelegraphy stations for the Armée de l'Air has brought out the weaknesses of the standard radio system. Deficiencies of the present system are pointed out and principles of a new system described. Rev. du Ministère de l'Air, October 1936, pages 1283-1291.

Radio. L. Portier. Present and future applications of radio in the field of aeronautics are discussed and suggestions made to direct research towards the number of problems which remain to be solved. Various systems are described. L'Aérophile, Special Ed., November 1936, pages 63-69. 9 illus.

The Radio Compass and Its Applications to Air Navigation. H. Busignies. R. C. 5 automatic directional radio compass which indicates the direction of a station on a dial graduated in 360°. Long description. L'Aérophile, November 1936, pages 256-259. 8 illus.

Radio Air Navigation. R. Denman. Trend of British development. Existing types of aircraft direction finder will probably be superseded by a form of cathode-ray direction finder giving rapid and automatic bearing indication, such a device having already been tested in America. Direction finding on ultra-short wave lengths does not seem at all promising, at any rate on board aircraft. Navigational needs of commercial flying in Great Britain will mainly continue to be supplied by medium-wave direction finding, speeded up by cathode-ray methods, reinforced by aircraft D/F bearings on ground stations, and relieved as necessary by the transfer of purely communication channels to shorter wavebands. Ultra-short-wave beacons, re-radiation of the ultra-short wave in aircraft, Phillips omnidirectional beacon, and radio for private flying are discussed. Comments by W. A. Duncan giving a "penetrating analysis" of the function of radio for control and navigation purposes are included. Flight, January 21, 1937, pages 54-56. 3 illus.

Radio Blind Landing Apparatus for Aircraft. W. Moser. Method of air navigation by means of radio, American methods for blind landing, preparatory studies for the development of a blind-landing system in Germany, and radio blind-landing apparatus, including ground apparatus such as the direct transmitter and the transmitter signalling airplane flying over the airport, and apparatus used on aircraft. Telefunken-Zeitung, November 1936, pages 5-18. 26 illus.

Vital Cooperation. H. A. Taylor. British airport and area control methods developed during the past decade and the need for rationalization. Flight, January 21, 1937, pages 50-52. 9 illus.

Armament

Spain as a Proving Ground. A German gun somewhere about the 37 mm. of the American Armament Corporation's gun is being tried out on German airplanes of the Spanish Nationalist Army. It is said that the gun has a muzzle velocity of 850 meters per second, and between two and three times the range of an ordinary machine gun. Brief reference. Aeroplane, December 23, 1936, page 790.

Whither Armament? H. F. King. "The 'cannon' germ is already gaining a hold across the Atlantic."

The discussion includes:—arguments for the adoption of the "canon" on British airplanes; its adoption as standard equipment by France, Turkey and Poland; the Hispano "moteur canon"; disadvantages in applying the "canon" to radial and inverted engines; suggestion for combining the "moteur canon" installation with a pair of outboard "canons"; installations of outboard "canons" on the Polish P.Z.L. P.24 and French Loire models; "canons" in the fuselage of the Fokker G.1, Potez 63 and Hanriot 220, especially the installation on the G.1.

The American Armament Corporation 37-mm. aircraft gun is described and difficulties in mounting the gun are outlined.

Illustrations include a drawing of the arcs covered by the guns of the Amiot 144, the 37-mm. aircraft gun of the American Armament Corporation, the Salmson inverted-vee-twelve engine arranged to accommodate a "canon," a stand for testing the Oerlikon FF "canon" at various angles of elevation and depression, two "canons" mounted in fairings below the fuselage of the Potez 63 fighter, nose portion of the Fokker G.1 showing installation of the "canons" and machine guns, shell for the 20-mm. Madsen, and installation of a drum-fed machine gun and 20-mm. "canon" on the Loire 46 fighter. Flight, December 17, 1936, pages 654a-654d, 655. 11 illus.

Cross Fire from High-Speed Airplanes. P. de Valroger. Cross fire is defined as fire from a "canon" located in any position on the airplane in which the axis of the "canon" makes an angle greater than 10° with the aerodynamic velocity of the airplane.

Bearing of the projectile on its path in the case of cross fire is considered theoretically. The angle is assumed to be about 90° and effect of the weight is neglected. The case for the round shot and a scored projectile, motion of the center of gravity and around the center of gravity, Magnus effect, return on the motion of the center of gravity; and final motion are discussed and suggestions made for experimental verification. Theoretically, the path of a normal projectile, fired athwart, appears practically rectilinear. Rev. de l'Armée de l'Air, August 1936, pages 851-862. 7 illus.

More About Aerial Torpedoes. Folland design for a torpedo submitted to the British Air Ministry in 1923. The torpedo was intended to be controlled by radio from the carrier or parent airplane and, on being released, to go into a steep dive with its angle thereafter and its lateral direction controlled by the operator. A few details. Aeroplane, Aeronautical Engrg. Sup., December 30, 1936, page 833. 4 illus.

Air Forces

Fleet Air Arms of the World. H. F. King. "The British Navy has more vessels devoted exclusively to the operation of aircraft than any other power." Aircraft of the Fleet Air Arm are discussed and British aircraft carriers are compared with those of the U. S. Navy. A group of the world's largest aircraft carriers is reproduced to scale including those of the United States, Great Britain, Sweden, Japan, France, and Australia. The Curtiss SOC-1, Grumman SF-1, Vought SBU-1, Douglas XTBD-1, Curtiss BF2C-1 and Vought XSB2U-1 planes are also illustrated in the first article.

The second article takes up Naval aircraft and carriers of the United States, France, Italy, and Japan. Very little, if any, of the Japanese aeronautical equipment is considered of up-to-date design but a formidable force of aircraft carriers is said to be a feature of the Japanese navy. To be continued. Flight, January 14 and 21, 1937, pages 34, 34a-34c and 62a-62d. 20 illus.

"Twins" for Carriers? "France, certainly, and America, so it is said, are experimenting with twin-engined monoplanes planned for deck landing." Brief reference in short editorial. Flight, January 7, 1937, page 3.

Europe Manufactures Planes. S. P. Johnston. Survey of the aircraft production activity in England, Germany, and France and clues to the general state of affairs in the factories of these countries. American Machinist, January 13, 1937, pages 4-5. 1 illus.

Europe Rearms in the Air. S. P. Johnston. Twenty-five to thirty thousand military aircraft could probably be mustered by the five major European powers today and this number may be doubled by the Fall of 1937. Germany alone has about 7,000 military airplanes and a probable production rate of 10,000 a year. Russian military air strength is in the 7,000-8,000 machine range. French military and commercial aircraft have not been advancing, both as to quality and quantity, at as rapid a rate as those of other European powers.

The discussion considers: the rise of Germany to a ranking air power, its aircraft factories, evidence that aircraft production tended to outrun engine production, and rumors of pilot shortage; Russian air-mindedness and new methods of training parachute jumpers; nationalization of the French aircraft industry; England's "Shadow Scheme" and evidence of its weakness as pointed out in Parliamentary discussions; and new tactical concepts in Europe with regard to the training of parachute jumpers, and the building of aircraft and engine factories designed to minimize danger from falling bombs, to operate at night without showing light from the outside, and to provide bomb- and gas-proof cellars for workers. Aviation, January 1937, pages 28-30, 70, 73. 3 illus.

Australia

An Americanised R.A.A.F.? Australian Defence Minister's plan to order forty airplanes mostly of an American general-purpose type from the newly formed Commonwealth Aircraft Corporation of Australia. Brief editorial. Flight, January 14, 1937, pages 23-24.

Canada

Canada proposes to spend $12,000,000 during the fiscal year beginning April 1 on air defenses, $6,000,000 more than is being spent during the present year. The plan includes 12 combat, 3 army cooperation, 7 flying boats, 24 bombers, 11 torpedo bombers, 18 coastal resistance, and 27 training planes. The permanent air force will be increased from 147 officers and 933 men to 195 officers and 1,498 men. Brief reference. Business Week, January 23, 1937, page 54.

Egypt

The Four Winds. A sum of £300,000 has been allotted by the Egyptian Minister of War in the Draft Budget for the purchase of twelve bombers from Great Britain. Brief reference. Flight, December 31, 1936, page 695.

Foreign Service News. About £300,000 is to be spent on British airplanes for the Egyptian Army Air Force to bring the number of machines up to 49. The Air Force hopes for 100 by 1941. Brief reference. Aeroplane, January 6, 1937, page 14.

France

The Reorganization of the Armée de l'Air. Duties of the supreme command, new air formations, stations of units in times of peace, and three important measures for improving the efficiency of the staff, including reduction of age limit, reinforcements, and reorganization of training centers. Rev. du Ministère de l'Air, October 1936, pages 1231-1259.

The French Aeronautical Field. Captain Durand. Equipment for French aviation squadrons is discussed, including landing fields, technical installations (hangars and other buildings), barracks, lines, railroad shipping facilities, water, heating, illumination, regrouping of installations, and the particular construction of buildings. Abstract from Science et Industrie. Rivista Aeronautica, December 1936, pages 416-427. 1 illus.

Germany

The Four Winds. A seaplane version of the Heinkel He51 single-seater fighter (750-hp. B.M.W. engine) is in service with the German Air Force. Brief reference. Flight, January 7, 1937, page 11.

The Four Winds. Fatal accidents in the German Air Force last year during training were ten times as numerous as those in the R. A. F. Brief reference. Flight, December 31, 1936, page 695.

On the German Air Force. C. G. Grey. The target of the bombing school is a complete village with railway stations and tracks. It is bombed with real bombs so that the Luftwaffe could find out not only whether their pilots could hit a target but what would be the effect of bombs of different sizes on buildings of different sizes and the length of time needed to put a railway line out of action. Visits to the technical school at Gatow-Kladow and the second group of the Richthofen Geschwader. Continuation. Aeroplane, December 23, 1936, pages 799-804. 12 illus.

Great Britain

Aeronautics in 1936. The British government program for the expansion of the aircraft industry, technical developments in transforming aircraft production methods to other systems, application of mass production methods, the Vickers-Wallis geodetic system, advances in civil aeronautics, and the less striking progress in aircraft engines are discussed. Reference is made to the Bristol Pegasus engine developing 1010 hp. on an all-in net dry weight of 1018 lbs. and to the Napier Culverin compression-ignition 720-hp. weighing 2.48 lb. per h.hp. Engineer, January 1, 1937, pages 2-3, 16. 8 illus.

The Balloon Barrage. Equipment for the balloon barrage for the defense of London has been ordered. The balloon barrage will be the responsibility of the Air Ministry and will be organized on the lines of the Auxiliary Air Force. Aeroplane, December 16, 1936, page 766.

Brief outline of plan for the defense of London. U. S. Air Services, January 1937, page 38.

British Military Aircraft of 1936. Handley-Page Harrow heavy bomber, Vickers Wellington long-range bomber, Vickers Supermarine Spitfire single-seater fighter, and the Bistol Blenheim bomber. Photographs only. Engineer, Supplement, January 1, 1937. 4 illus.

The Charmed Circle. Further debate in the House of Lords on the problems of Imperial security. Aeroplane, December 23, 1936, pages 793-794.

Communications and Catapults. C. M. McAlery. Air defense of the British sea communications and an account of the development of the aircrait catapult by H. J. C. Harper. Abstracts from two articles said to be of special interest to the ocean-going side of the Royal Air Force and taken from the Journal of the Royal United Service Institution, August, 1936. Aeroplane, December 30, 1936, pages 827-828. 3 illus.

The Engineering Outlook. Expansion of the British aircraft industry, the rearmament plan, involving the increase in the first-line strength of the R. A. F. to 2500 machines by 1939, with reserve equipment on a full war basis, estimated degree to which the planned development in first-line strength has been achieved, estimates for airplanes and spares, 1935 and 1936, the "shadow" industry, advance in air-cooled engines, suspension of Diesel-engine development, and exports of British aircraft. Engineering, January 8, 1937, pages 44-45. 7 tables.

Fighter Formations. New and interesting formations introduced in the flying of fighter R. A. F. squadrons. There are at present eighteen regular and four auxiliary fighter squadrons in England. Aeroplane, December 16, 1936, page 765. 1 illus.

Air and Water. The British Ministry has decided to increase the number of aircraft in most of its squadrons. Fighter squadrons will be increased from 12 to 14 machines, heavy bomber squadrons from 10 to 12 machines, and flying-boat squadrons from four to six machines. In the new category of general reconnaissance units every squadron will have 18 aircraft. Total of aircraft in units abroad at the end of the expansion will be about 415, making a total at home and abroad of 2,165. Brief reference. Engineer, January 15, 1937, page 77.

The Four Winds. Anti-aircraft armament of British battleships is being more than doubled and all vessels of this type are being supplied with deck armor and aircraft.

Miles Nighthawks (D. H. Gipsy Six engine) for the R. A. F. will be used both for training and communication work. Brief references. Flight, January 14, 1937, page 30.

On Progress or Otherwise in 1936. C. G. Grey. "On the whole 1936 has been a disappointing year in aeronautical progress when you consider the millions of money that have been flung about by the Air Ministry in obedience to the scared politicians who ordered them to produce airplanes like rabbits out of a conjurer's hat, regardless of whether those aeroplanes could be of the slightest use in a real war or not. The discussion covers the greater attention paid to the air cannon, improved parachutes, the high-speed bomber, airport follies in not providing bomb-proof hangars, Fleet Air Arm progress in catapults for ships of the Royal Navy, lack of subterranean storage, and real progress as shown in the design of the Short flying boats and the little Heston twin-motored cabin monoplane. Suggestions to be followed for future progress are added. Aeroplane, January 6, 1937, pages 4-8. 9 illus.

The Royal Air Force in 1936. C. M. McAlery. "Mobility, adaptability, and reliability, three essential qualities in a fighting service, were well demonstrated by the R.A.F. during 1936."

Reorganization of the command and administration of the Home Defence Air Force, expansion of the R.A.F., operations and exercises, displays and competitions, appointments and casualties are discussed. Aeroplane, January 6, 1937, pages 9-11. 8 illus.

Some Nautical Contrasts. Standard flying boats (Supermarine Scapa and Stranraer, Short Singapore III, and Saro London) in the service with or ordered for the R.A.F., are shown in comparison with the Short Empire Boat to indicate that none of the Service machines represents ultra-modern practice in the design of aircraft of this class. Photographs only. Flight, January 14, 1937, page 27. 5 illus.

HOLLAND

The Four Winds. Sixteen Fokker long-range heavy bombers have been ordered by the Dutch government. Brief reference. Flight, January 21, 1937, page 53.

ITALY

Contribution of Aeronautics in the Creation of the Empire. Ten. Col. V. Liov. Part played by the Italian air force in the Ethiopian undertaking is described with statistical data. Rivista Aeronautica, November 1936, pages 163-197. 12 illus.

KENYA

Kenya's Air Garrison. Formation of bomber squadron in Kenya. Brief editorial. Flight, January 14, 1937, page 26.

PORTUGAL

Foreign Service News. Ten Junkers all-metal bombers with machine guns, radio, and photographic apparatus have been delivered by the makers to the Portugese Army Air Service. Brief reference. Aeroplane, January 6, 1937, page 14.

SPAIN

The Four Winds. The Vultee monoplane Lady Peace used by Richman and Merrill for their double Atlantic crossing has been sold to the Spanish Loyalist government. Brief reference. Flight, January 21, 1937, page 53.

SWEDEN

The Four Winds. The Swedish Air Force has placed an order for 36 Junkers 82 bombers. Brief reference in first issue, photograph only in the second. Flight, December 17 and 31, 1936, page 651 and 695. 1 illus.

U. S. A.

The Army. Major General O. Westover. Changes in aircraft employment and detailed operation brought about by the modern military airplane, capabilities and limitations of our own personnel and equipment, extended flights for special training of air personnel, and aerial defense measures. Aviation, January 1937, pages 22 and 64. 2 illus.

The Four Winds. Curtiss P-36 pursuit airplanes ordered by the U. S. Army Air Corps are powered with Pratt and Whitney Twin Wasps giving 1000 hp. for take-off. Brief reference. Flight, December 24, 1936, page 673.

The Navy in 1936. Rear Admiral A. B. Cook. Accomplishments in Naval aviation during the past year reviewed with reference to the provision of the best available aircraft to the Fleet, number of aircraft and engines overhauled, shortage of operating facilities on shore, and aviation training. Aviation, January 1937, pages 23, 62. 2 illus.

Foreign Service News. Reference to the War Department order for 120 North American observation airplanes of a new type powered with a 850-hp. engine and said to be 20 m.p.h. faster than any observation airplane now in use in the U. S. Army Air Service, and to the recent accident to the Boeing YB-17 said to have a range of 3,000 miles and a top speed of 250 m.p.h. "The War Department originally ordered 13 of these machines but the program has now been suspended." Brief. Aeroplane, December 23, 1936, page 798.

Secretary Woodring Would Expand Air Force. Gradual building up of an enlisted reserve to a strength of 150,000 men and speeding up of the Army aircraft procurement program. Summary of recommendations in annual report. Brief. U. S. Air Services, January 1937, page 33.

Inevitable? "U. S. Army officials believe that any attack upon this country will be largely aerial and the Edgewood arsenal at Washington is turning out thousands of gas masks for any national emergency. Raw materials and all parts are tested and retested to insure the maximum amount of safety to wearers." Brief reference. Business Week, January 23, 1937, page 50. 1 illus.

An Opportunity for Congress. Appropriations for new airplanes for the Army and Navy are urged in a brief editorial. Aero Digest, January 1937, page 29.

U. S. S. R.

The Flying Bear. R. D. Hudson. Present position of the Soviet Air Force in regard to airplanes and production of aircraft and engines, as reported in the British Daily Telegraph newspapers. Aeroplane, December 30, 1936, page 824.

Nationalized Aeronautics. P. A. Richards. Aviation in U.S.S.R. L'Aérophile, November 1936, pages 242-248.

Air Warfare

The Aerial Defense of the British Empire. Colonel F. von Bulow. Influence which the development of aerial power exerts on the military organization of Great Britain. Task of the air forces in the defense of the Empire, the British civil airlines as a factor in aerial defense of the Empire, aerial defense of the Metropolitan area, the Mediterranean and the Arabian countries, and the Far East are discussed. Long article from Militaerwissenschaftlische Rundschau, No. 3, 1936. Rivista Aeronautica, November 1936, pages 242-255. 3 illus.

Air Warfare. "Aerial Warfare and Populations," General Fequant. "Aerial Warfare in 19—?" (Extracts from the Course in Aerial Military History at the Training Center of the Armée de l'Air in 1950-1951) Lt. Col. Bellenger. "Naval Aeronautics." Articles included in the special edition of the magazine entitled "The Potential World Aviation." L'Aérophile, Special Edition, November 1936, pages 6-19. 7 illus.

Foreign Service News. Participation of airplanes in the Spanish Civil War from November 13 to December 16. Brief. Aeroplane, December 23, 1936, page 798.

Imaginary Bombardment. Captain Pommarel. Six operations in bombing instruction with some criticisms. Rev. du Ministère de l'Air, October 1936, pages 1293-1301. 3 illus.

The Influence of Air Power upon History. C. Caldwell. "Air power will cause huge cities to vanish as congested units, to be rebuilt in hundreds of smaller segments, altering the face of the countryside the world over. It will force migrations of peoples by the millions; it will alter the course of nations and of empires. In our lifetime it will rule and change the world."

With air power dominant, an island-controlled empire today is said to be an impossible political entity and the British Empire as an island-controlled political entity not to be able to survive the next major war. Apparently unrelated matters which, considered in their relations to each other, lead to this conclusion are discussed, including area and population of England, method of supplying foodstuffs and materials for manufacture, distribution of raw materials and manufactured goods in world commerce, capability of modern war planes, submarine campaign of the War of 1914-18, and the Italian conquest of Ethiopia. Aero Digest, January 1937, pages 19-20, 58. 2 illus.

The Metropolitan and the Passive Defense of Paris. A. Ferrant. Two anti-aircraft shelters said to be the safest in the world and located in the subway network. Rivista Aeronautica, November 1936, pages 235-242. 11 illus.

Power of the Air Forces and the Element of Stratagem. Commandante V. Pivetti. Data derived from experience in aerial transalpine navigation on Italian and foreign civil airlines are analyzed and the efficiency considered of an aerial armada which, properly prepared, could overcome the disturbing elements in navigation of this section and surprise the enemy. Rivista Aeronautica, November 1936, pages 198-210.

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